ELECTRIC RAILWAYS AND TRAMWAYS,

THEIR CONSTRUCTION AND OPERATION.

A PRACTICAL HANDBOOK,

Setting forth at length the modern application of Electricity as a Motive Power for Railways and Tramways; containing Complete Financial and Engineering Data as to Design, Construction, Equipment and Working; fully Illustrating all modern and accepted types of Machinery and Apparatus; and describing in detail the principal Installations of Europe and America.

BY

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LORD KELVIN.

NOTE.

IT may fairly be said that no complete and up-to-date treatise on electric motive power applied to railways and tramways exists at the present time; and it is believed that such a publication will fill a want which is felt not only by the engineering profession and by tramway managers, but also by many shareholders, landowners, and others, who are directly affected by the questions involved in increased and improved rapid transit facilities.

This belief is greatly strengthened by the general interest shown in the series of articles on "Electric Traction" which have appeared in the columns of *Engineering* since January, 1895. These articles form the basis of the present book, but the descriptive and statistical matter has been most thoroughly revised and brought up to date, and recent developments have been carefully noted.

Of the importance of the subject there can be no doubt. Electrical motive power has during the past few years made most astonishing progress. In the United States and Canada it has already practically superseded every other means of tramway and light railway traction. Upon the Continent of Europe a similar movement has now assumed substantial proportions. In many of the Colonies electric lines are in operation or under construction. In Great Britain a number of electric railways and tramways are running with most satisfactory results, and a widespread interest is taken in the extension of tramway and light railway services.

Such being the present state of affairs, it has been the wish of the author to lay before his readers a complete statement of electric traction as it now exists: the conditions under which its use is permissible and advisable; the machinery, plant, and apparatus now obtainable; the

design of stations, and the method of installing a line to the best advantage; the rules, regulations, forms, methods of accounts, etc., which have been evolved from the actual practice of important lines.

The data given have been personally collected by the author, who, with this end in view, has visited almost every great city and representative plant of the United States and Europe.

With much pleasure the author acknowledges the assistance rendered him by Mr. James Dredge, of *Engineering.* To him, as friend, editor, and publisher, the author is greatly indebted for his constant and kindly interest, and for the valuable advice which his wide experience in scientific and engineering publications so well qualifies him to give.

In the preparation of this book the author has been greatly aided by the courtesy extended to him by the owners, engineers, and managers of electric traction plants, as well as by the manufacturers of the machinery and material used in their construction, and by the technical press.

His obligation to these gentlemen is too great to be set forth in detail in a prefatory note, but to them as a body he desires to express his most grateful acknowledgement.

The author's thanks must, however, be especially offered for the willing and ready aid which he has constantly received from Mr. Robert W. Blackwell, a pioneer of electric traction progress on both sides of the Atlantic, to whose wide experience and great practical knowledge of electric railway construction and working he owes much which may be found to be of value in this volume.

PHILIP DAWSON.

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ERRATA.

Page 37. Eighteen lines from bottom of page reads "25 amperes" instead of "24 amperes."

,, 44. Third line from bottom of page reads "insulated return feeders" instead of "insulated return figures."

,, 416. Bottom line of page reads "220 tons" instead of "210 tons."

,, 480. Table C., total should read "£10,484 12s. 10."

,, 482. Table CIV., total should read "6.1596."

ELECTRIC RAILWAYS AND TRAMWAYS,

THEIR CONSTRUCTION AND OPERATION.

CHAPTER I.

INTRODUCTORY AND GENERAL.

IT will probably be admitted that there is no engineering question of more pressing present interest to the profession, and to the British public at large, than those involved in the extension of rapid transit facilities.

The conditions of modern metropolitan life imperatively demand that the ever-increasing population of our cities should be afforded vastly increased and improved means of intramural circulation. Moreover, our overcrowded centres of population can no longer accommodate the great class of workers and their families, and access to outlying suburban districts must be facilitated by every possible means. If only for hygienic reasons, it is indispensable that the accessible residential zone surrounding our greater cities be extended to the utmost limit within our power.

Nor are these the only pressing demands. Our agricultural, mining, manufacturing, and fishing districts are already clamouring for some means whereby their products shall be brought more readily to railway centres or to local markets. Freedom of trade and the development of the great lines of transportation have poured the produce of all the world into Britain, and the costs of carriage and handling are certainly at present most adverse to the home producer, placing him on disadvantageous terms for competition.

It may fairly be questioned whether traditional British conservatism and the non-elasticity of the rules by which the construction, equipment, and operation of our railways and tramways are governed, are not responsible for a condition of affairs which both engineers and public already regard as thoroughly unsatisfactory.

A remedy must certainly be found in the near future, and to that end

careful study should be made of the progress of other nations in the solution of the problems involved.

It is of necessity that we first look to America for those later developments in rapid transit extension, which have led to the introduction of improved mechanical traction on a large scale. While other countries as well have been pushing forward in this regard, the necessities of the great Transatlantic Republic have exceeded those of all other nations, and in the struggle to keep pace with population increase, and to effectively develop every resource, both inventor and capitalist have been kept upon their mettle. The results obtained have been so rapid and surprising, and, as a whole, so satisfactory, that they merit our most careful attention.

We are already familiar with American steam and cable railway practice, and have profited thereby to such an extent as has seemed applicable to English conditions. In the application of electricity to surface railways and tramways we have made but little progress. Such installations as are now in operation in the United Kingdom are small, and must be regarded as largely tentative and experimental.

It is the chief aim of the author to describe as briefly as may be the present state of electrical traction in the United States and Canada. The data quoted have been carefully collected during a recent journey through America, to which six months were exclusively devoted. Almost every great centre has been visited, and the varying methods of construction, equipment, and operation carefully studied. With that generosity characteristic of American engineers, every facility for obtaining information, and comparing results, was afforded, and the author wishes to take this opportunity of expressing his deep obligations for the great assistance thus rendered him. The progress made in Europe is also described and set forth in tabular form, but as English and Continental practice differ in no essential feature from the American, it is not necessary that it should be treated in such detail. At the same time, an attempt is made to do justice to those European engineers who have done good work in this field.

For convenient treatment, the general subject is divided as follows:

1. Introductory and general.
2. Permanent way.
3. Return circuit.
4. Aerial conductors.
5. Motors and gearing and their accessories.
6. Rolling stock.

7. Generating plant.
8. Power stations and buildings.
9. Description of typical lines.
10. Railway locomotives and elevated roads.
11. Maintenance and efficiency.
12. Specifications.
13. Organisation and accounts.
14. The conduit.
15. Accumulator traction.
16. Working expenses and statistics.

* * * * * *

For many reasons the current American appellation "street railway," is greatly preferable to the indefinite English term "tramway." The latter word is distinctly unsuitable for use in connection with modern mechanical traction. It still carries with it, from its original significance, the idea of something small and petty. The great American metropolitan and suburban lines operated by cable or electric power, are railways in every sense of the word, having equal financial dignity with the steam railway, requiring at least equal engineering skill and fertility of resource, and exercising a much greater and more constant influence upon the life of the people at large. The word "tramway" is now a misnomer, except in so far as it may refer to those methods of operation and equipment which have had their day, and will soon be no longer tolerated.

The growth of the street-railway industry in the United States has been most rapid, and characterised by extraordinary energy, enterprise, and confidence on the part of promoters, operators, and investors.

American conditions have always been most favourable to the street railway. In the early days every inducement was naturally offered to whoever would embark capital in the development of transit facilities. Franchises were easily obtained, and the restrictions imposed were few and light. Long terms and valuable routes were freely granted to companies and individuals who were prepared to exploit the privileges offered them. By the community at large the street-railway man was regarded rather as a benefactor than otherwise.

Taken as a whole, the privileges granted have not been abused, and the public at large has profited by the liberal line of policy adopted. The street-railway owner quickly found that the only path to success lay in

affording a thoroughly satisfactory service, and devoted himself to this end with all energy. The opportunity for lucrative investment attracted men of large capital and highly developed commercial instincts. To-day we find the principal owners and managers of American street-railway interests among the most prominent and respected citizens of their respective communities, standing in the first rank socially, politically, and financially.

It is due to their energy and far-sighted policy that the street railways of America are now the best in the world, well equipped and operated, and in every sense an essential and most commendable public service.

Beginning with a single line, constructed in New York about 1850, American street railroads show a practically unbroken record of financial success. Only six or eight lines were built prior to 1855, about 30 in the next five years, over 80 in the succeeding decade, and so on in rapidly increasing ratio.

The following figures show the ratio of street-railway-track mileage in a number of American cities and towns in 1893, differing widely in population:

TABLE I.—RATIO OF STREET RAILWAY MILEAGE TO THE POPULATION OF SIX AMERICAN CITIES.

Name.	Population.	Miles of Tramway.	Ratio of Mileage to Population.
Seattle ...	60,000	102	1 to 588
Denver ...	106,600	275	1 „ 720
San Francisco ...	297,900	244	1 „ 1221
Boston ...	446,500	279	1 „ 1600
Baltimore	434,100	222	1 „ 1955
Chicago...	1,098,500	513	1 „ 2141
New York	1,513,500	294	1 „ 5180

To the comparatively small mileage of street railways of New York should really be added the great system of elevated railways which run over more than 50 miles of its principal thoroughfares, carrying more than 221 million passengers annually. Chicago has also extensive lines of elevated railway.

Comparing the above figures with those of English cities of approximately the same population, we gain an idea of the extent to which the street railway enters into the life of a modern American city.

TABLE II.—Ratio of Street Railway Mileage to the Population of Five English Cities.

Name of Town.	Population.	Miles of Tramway.	Ratio of Mileage to Population.
Northampton ...	70,872	6	1 to 11,812
Blackburn	120,064	8.5	1 „ 14,125
Leeds ...	367,506	23	1 „ 15,978
Liverpool	517,980	61.5	1 „ 8,422
London	5,633,806	250	1 „ 22,523

In the United States street railways, and, to a limited extent, steam-worked metropolitan elevated lines, constitute the chief means of passenger transit; omnibuses having never been able to make head against the all-prevailing street cars, the badness of paving in the early days having prevented any general use of cabs, and *réseaux* of suburban steam railways such as we know in England being practically non-existent in America.

In 1873 the Hallidie cable system was first introduced in San Francisco, and its pre-eminent value, where heavy grades had to be encountered, was fully demonstrated. Within the next 12 years important lines in San Francisco, Chicago, New York, and Philadelphia were equipped with cable traction plant.

The history of electric traction extends over a period of well-nigh half a century. As in the case of most similar developments of applied science, that history is largely a record of disappointment and failure of tests which promised much from a theoretical standpoint, but which wholly failed to demonstrate any probable practical value.

The self-contained car carrying a sufficient store of energy for a given period of operation was long the only idea of the inventor. The first radical departure was made by Siemens at the Berlin Electrical Exhibition of 1879, where a stationary generating plant furnished power to the motors on the cars, the rails serving as the connecting medium. This, and the success achieved by the cable tramway, turned the tide of experimentation towards the evolution of a workable system of sub-surface conductors.

In 1883 the demand for a mechanical power, applicable to the requirements of street railways which could not afford to undertake so large a financial investment as was necessary to instal a cable system, had become a recognised fact.

Prior to that time many experiments had been made with a view to adapting the electric motor to railway necessities, and in 1883 the first

electric line actually doing business was opened at the Chicago Exposition by the company formed to exploit the inventions of Field and Edison.

From 1883 to 1888 the Bentley-Knight, Daft, Van Depoele, and Sprague Companies were actively engaged in developing the details of a commercial electric system. It was not, however, until 1884, when the overhead conductor was introduced, that any really practical solution of the problem seemed possible, and the succeeding four years were devoted to the elaboration of the many details connected therewith, and to the development of a type of apparatus which electrically and mechanically could withstand the excessive strains inseparable from tramway service. From an engineering standpoint great progress was made during that period, and many difficulties overcome. No effective and practical commercial result was, however, reached until the Thomson-Houston, Edison, and Westinghouse Companies entered the traction field, absorbing the smaller pioneer companies, and bringing their great experience and financial support to the development of the infant industry.

Under their auspices phenomenally rapid progress was made, and at the close of 1889 the entire success of the electric system had been demonstrated beyond question.

A Table showing the relative progress made by the several systems systems of motive power since that time will be found in the statistics given at the end of this volume.

In 1890 there were 2,523 miles of electrically operated track and 5,592 motor cars within the United States and Canada. In July, 1895, 10,752 miles of electrical conductors had been erected, furnishing current for 35,004 electric cars. Approximately these figures mean an investment in equipment of £80,000,000 sterling, and two and a half million horse-power in engines at the power houses of the traction companies.

In 1891, the total investment in electrically equipped tramways in the United States was £7,166,000. Now over three-fourths of the total tramway movement of the country is electrical.

This enormous introduction of a new mechanical power has been almost wholly effected within the last six years. The overhead wire and the "trolley-car" were vigorously opposed in many quarters at the outset, but the people at large, quick to appreciate the great advantage of better and more rapid transit facilities, have always given the weight of their approval.

While the rapidity with which electric traction has secured universal acceptance and adoption in America is well known to us, it is very doubtful

whether we fully appreciate the extent and importance of a similar movement in Europe, or of the results already attained, especially on the Continent.

As a matter of fact, the progress made has been most remarkable, and both engineer and financier have displayed the greatest enterprise in adapting to European needs the system of electrical motive power which has so conclusively demonstrated its superiority in the United States.

It has been repeatedly stated by the American engineers who have from time to time addressed the several Societies, that the conditions prevailing on this side of the Atlantic, so far as traction is concerned, differ in no essential feature from those which they had to encounter a few years ago. They confidently predicted that the manifold advantages of the electric "trolley-car" would induce its adoption in Europe on a scale well-nigh as extensive as in America; and that, with the introduction of mechanical power, the social status of the tramway would be vastly improved, and it would take its rightful place as an essential public convenience.

To a certain extent this prediction has already been fulfilled. The electric railways of Europe have closely followed the most approved American practice. With but few exceptions, all employ a single elevated conductor, using the rails to complete the circuit. Dynamos, motors, speed-controllers, &c., are in every practical particular the same as those which have been developed by American engineers and electricians. It could not well be otherwise, for nothing but experiment on a grand financial scale could definitely establish the commercial value of so radical a departure from established traction methods. That practical test having been applied in the United States, we cannot be blind to the immense advantage to Europe of having the results attained, at its full and free disposal.

The only possible particular in which a divergence from the American system has been made is in the steam engine plant, and therein American engineers show a decided tendency to adopt European methods in future installations. Large direct-coupled units and condensing plants have been employed in many of the great installations more recently made.

The path to the introduction of electric traction in America was undoubtedly smoothed by the valuable results attained by the cable system. Formerly, bitter contention existed between the adherents of the two systems. It may be fairly said to-day that they do not compete, and that each has found its peculiar and appropriate place. For great and constant

passenger traffic, at stated speeds, in broad and straight thoroughfares, and where the conditions are such as to induce the investment of large capital upon ordinary commercial terms, the cable system has no equal, and the same is true where long and steep gradients are encountered. In Chicago, New York, and San Francisco the cable system is at its best. In smaller towns, where the traffic is not so great, where curves and branches are of constant occurrence, where suburban routes are in question, or where the cost of roadbed and power plant must be kept within reasonable bounds, the electric system found a field that the cable system could never satisfactorily fill.

In the great centres of population, cable and electricity work harmoniously together as component parts of the same system, each fulfilling that portion of the service to which it is best adapted.

Approximately, the two systems compare somewhat as follows :—

TABLE III.—Comparison of Cost and Efficiency of Cable and Electric Street Car Lines.

	£	£
Cost per track-mile of cable and conduit	10,000	to 30,000
" " electrical conductors	500	" 2,000
" " complete cable equipment... ...	18,000	" 50,000
" " " electrical equipment ...	2,000	" 10,000
	Cable.	**Electric.**
Average effective horse-power applied to axle of each car on the line	3 to 5	4 to 10
Average indicated horse-power at engine per car on the line	4 " 10	6 " 20
Friction load in per cent. of total load	50 " 65	40 " 60
Coal consumption per car-mile ... ... lb.	5 " 8	5 " 10

It may here be said that it is a frequent error to criticise the low mechanical efficiency of cable and electric railways. What we might perhaps call the financial efficiency is the point really at issue. The system desired is that which, upon a given possible investment, will make the best return. The higher the mechanical efficiency, without detriment to financial results, the better. To ensure financial efficiency, the construction must be such as to secure a low rate of depreciation, an object kept well in view by the more prominent manufacturers of both electric and cable railway apparatus.

The data in Table IV., of comparative costs of operation, have been tabulated from information most courteously afforded the writer by the

managers of several large and well-managed American street-railway lines. (The names are suppressed by request.)

TABLE IV.—Comparative Cost of Operating Cable, Horse, and Electric Street Railroads.

Designation of Company.	A.			B.			C.		D.	E.	F.	G.
System of Traction Employed.	Cable.	Horse.	Electric.	Cable.	Horse.	Electric.	Cable.	Horse.	Electric.	Electric.	Electric.	Electric.
Transportation, pence per car-mile	2.3460	5.2315	3.3930	...	...	...	5.45	6.37	2.255			
Motive power in pence per car-mile	0.4980	4.8470	0.7350	...	...	...			0.925			
Maintenance of track, paving, and buildings, pence per car-mile	0.9200	1.2910	1.0020	...	...	...	1.69	0.44	0.420			
Maintenance of rolling stock in pence per car-mile ...	0.5340	0.3950	1.0785	...	...	...	0.21	0.89				
General expenses, pence per car-mile	0.6626	0.6770	0.1215	...	...	...	0.41	0.31	0.850			
Total working expenses in pence per car-mile ...	4.9605	12.4415	6.3300	4.55	5.35	4.85	7.76	8 01	4.450	4.21	5.85	5.8
Ratio of working expenses to receipts, per cent. ...	49.69	80.07	40.00	77.69	96.81	79.55	...	...	58.5	58	61.5	79

In Table IV. transportation expenses include wages of all men necessary to work and run cars, car-cleaners, men in car-shed and material used by them, electric lighting and heating, &c., in fact, all expenditure directly applied to the transportation and accommodation of passengers.

General expenses include expenses connected with the administration, cost of securing traffic and miscellaneous expenditure, with the sole exception of taxes and interest on capital. The total expenses include everything except taxes and interest on capital.

The average ratio of working expenses to receipts on English tramways is 80.8 per cent.

The average working cost per car-mile on English tramways is 9.5d. ("Duncan's Tramway Manual").

Great difficulty is found in making any fair comparison of working costs per car-mile of cable and electric lines. Some electric railways have equipped every car with motors; many others have only a proportionate number of motor cars, and increase their carrying capacity during "rush" hours by coupling ordinary cars called "trailers" to the motor cars, as in steam railway practice. The trailers being much lighter than those cars which are mounted on heavy motor trucks, a trailer car-mile costs very considerably less than a motor car-mile. The same is the case in cable railways as regards the use of grip cars and trailers.

Street-railway managers consider the cost of operating motor or grip cars to be from two to four times that of trailers.

It may be taken that the average increase of indicated horse power and coal consumption at the station, required by the addition of trailers, is about half that which would be incurred if the same number of motor cars were added. The motor-car conductor can usually attend to the collection of fares in the trailer. In the foregoing Table only motor or grip cars are taken into consideration. On the electric lines cited in the Table, trailers are rarely used, except where the traffic is abnormally heavy, as on holidays. On the cable roads they are more frequently employed; one of the lines mentioned runs, as a rule, trains of four cars with a cable speed of 12 miles per hour.

In cases "B" and "G" the ratio of operating expenses to receipts is high, and it should be stated that these are lines with only a light traffic as yet, having been built to develop the value of suburban residential property. It may here be said that American results demonstrate the distinct importance to the landowner and builder of increasing rapid transit facilities to the greatest possible extent, before placing property on the market or endeavouring to secure tenants.

The following are the detailed working expenses per car-mile of an exceedingly well-equipped electric street railway, operating 150 miles of track, 130 motor cars, and 75 trailer cars. The motor-car mileage is three times as great as the trailer mileage. The Table shows how economically an electric line can be operated, even at high prices of both labour and material.

TABLE V.—Detailed Cost of Operating Large Electric Road.

	Pence per Car-Mile.	
Transportation:	d.	d.
Car service (conductors, motor-men, starters, motor inspectors, transfer agents, &c. ...	2.04	
Car-house expenses ...	0.16	
		2.200
Motive Power:		
Power-house wages, coal, oil waste, &c. ...		0.650
Maintenance of Track and Buildings:		
Track ...	0.015	
Buildings ...	0.010	
Overhead line ...	0.055	
		0.080
Carried forward ...		2.930

TABLE V.—(*Continued.*)

	Pence per Car Mile. d.	d.
Brought forward ...		2.930
Maintenance of Equipment:		
Power plant ...	0.045	
Tools ...	0.010	
Various equipment ...	0.010	
Motors ...	0.170	
Cars ...	0.175	
		0.410
Fixed charges ...		5.475
General Expenses:		
Salaries of clerks, &c. ...	0.140	
Office expenses ...	0.155	
Miscellaneous (legal, insurance, damages, taxes, &c.) ...	0.365	
		0.660
Total expenses per car-mile ...		9.475

TABLE VI.—Prices Paid for Labour in the Greater American Cities.

Conductors and drivers per day of 10 to 14 hours ...	6s. to 8s. 10d.
Mechanics per day of 10 hours ...	7s. „ 9s. 0d.
Foremen „ „ „ ...	8s. „ 10s. 0d.
Motor cleaners „ „ ...	5s. „ 6s. 0d.
Chief engine-driver in power-house, per month ...	15*l.* to 25*l.*
Chief electrician in power-house, per month ...	15*l.* „ 25*l.*

Horses cost from 10*l.* to 25*l.*
Mules „ „ 20*l.* „ 25*l.*

It is not unusual for a street railway to lease its supply of power—either from another railway, or from lighting and power-distribution companies—on a basis of a given rate per car-mile, or per kilowatt-hour; $1\frac{1}{2}$d. per car-mile, or from 0.55d. to 0.80d. per electrical horse-power, is about the rate charged for this service. At the latter rates, a company running cars 18 hours per day, and making 125 miles per car per day at an average cost in power of 10 electrical horse-power at the station switch-board per car, would pay the supply company from 8s. to 16s. per car per day.

Let us now compare the cost of horse, electric, and cable traction, with a view to determining under what special conditions each of these systems is applicable, and wherein the advantage of one over the other lies. For this purpose we will take three lines in the same city and under the same management, and compare their working expenses, the accounts of all three

lines being kept in the same way. The lines are of approximately the same length, and are working under fairly advantageous circumstances for each particular system.

TABLE VII.—COMPARATIVE COST OF WORKING HORSE, ELECTRIC, AND CABLE STREET RAILWAYS IN SAME CITY AND UNDER SAME MANAGEMENT.

	Horse.	Electric.	Cable.
Length of line in miles	$3\frac{1}{2}$	4	$3\frac{8}{10}$
Number of cars operated by horses...	13	—	—
„ motor cars	...	10	—
„ trains, 1 grip car and 1 trailer	...	...	17
Car mileage for six months...	175,455	233,287	802,718
Wages of ostlers, pence per car-mile	0.3460	—	—
Engineers and firemen „ „	...	0.2700	0.1480
Harness repairs, veterinary surgeon, water, &c., pence per car-mile	0.0690	—	—
Repairs, engines and machinery, pence per car-mile	...	0.0010	0.2455
Hay and grain, pence per car-mile ...	0.8435	—	—
Fuel for engines „ „	...	0.4145	0.2950
Horse shoeing „ „	0.1005	—	—
Oil and waste for engines „	...	0.0145	0.0130
Water for boilers „	...	0.0255	0.0285
Lubricants, dynamos and motors, pence per car-mile	...	0.0565	—
„ cables and pulleys „ „	...	...	0.0215
Renewal of live stock „ „	0.1770	—	—
Repairs, dynamos, and motors „ „	...	0.6115	—
„ and renewals of cable „ „	...	...	0.7125
„ conductors and trolley „ „	...	0.1455	—
Total in pence per car-mile ...	1.5360	1.5390	1.4640

The horse and electric lines considered in the above Table have easy gradients. The cable line in question has heavy gradients and crooked alignments.

Let us consider how the working expenses in the above three cases would increase with an increase in the number of cars operated. With horse traction the cost of motive power would grow nearly proportionately to the number of cars operated, or, in other words, the cost per car-mile would practically remain the same whatever the number of cars operated might be. With electric traction a different condition would exist—nearly the same number of engine-drivers, firemen, and quantity of waste and oil would suffice for a station of 500 horse-power as would for one of 100 horse-power. The cost of fuel does not grow proportionately with the number of cars, and, under favourable circumstances and good management, may increase but very slightly with a largely increased car-mileage. From a

large number of observations made on various systems, it may be taken that under average conditions the fuel increases with the car-mileage in the proportion of two to three. The same holds good for water. The repairs account for generators, motors, and line may be supposed to increase proportionately to the car-mileage.

In the case of cable lines, the cost of engine-drivers, firemen, lubricants for engines, cables, and pulleys remain nearly constant for any number of cars operated. The increased cost of fuel and water may be taken, as in the case of the electric line, to be proportionate to the car-mileage in the ratio of two to three, and the renewal and repairs of cable to increase with the car mileage in the proportion of two to four. From the above statement it is evident that whereas the cost per car-mile remains approximately constant with horses, no matter how traffic increases, both with electric and cable it decreases with the increase of car-mileage, and the decrease with the cable is more rapid than with the electric system.

Against cable roads stands their necessarily heavy capitalisation, and it follows that it is only in the case of lines having a very large traffic that the cable pays. It may be said, after careful study of existing cable roads, now operated successfully from the investor's standpoint in America, that for a perfectly level and flat road, supposing the average speed of the car to be 10 miles an hour, the cable becomes preferable to the electric system when the headway upon which the cars are operated is, during certain hours of each day, considerably less than one minute. Up to that point electricity is superior. Electricity undoubtedly finds a far larger field than the cable system.

From careful study of the data kindly furnished by a great number of American electric and cable roads, it appears that on an average a well-equipped and managed road can count on earning, in most cases, from 25s. to 50s. per annum per head of the population of the town or towns through which it runs. The introduction of mechanical traction has been demonstrated to cause an average increase of 30 per cent., and in many cases of cent. per cent. in the number of passengers.

The largest electric railway equipment in the United States is that of the West End Street Railway Company of Boston, Massachusetts. Its three power stations furnish an approximate total of 13,000 electrical horse-power. The average monthly electric car-mileage of this line in 1895 was 1,848,343 miles. On January 27, 1894, with 577 cars and 71 snow ploughs running, the consumption of electric power at Boston was as follows:

TABLE VIII.—CURRENT OUTPUT OF WEST END STREET RAILWAY, BOSTON.

Stations.	Hours Run.	Mean Current for the Day. Amperes.	Maximum Current. Amperes.
Allston	16	1,203	1,580
Cambridge	18	4,088	5,425
Central	24	12,706	14,400

The following figures, showing the rate of introduction of electric power during the past few years, are extracted from the annual reports of the West End Street Railway Company :

TABLE IX.—RESULTS OBTAINED BY THE INTRODUCTION OF ELECTRICAL MOTIVE POWER ON THE WEST END STREET RAILWAY, BOSTON.

To September 30 of	1888.	1889.	1890.	1891.	1892.	1893.	1894.
Total miles of track	..	233.24	234.69	244.00	259.80	268.33	272.89
Miles electrically equipped	..	..	65.46	81.23	148.04	182.50	212.47 (*f*)
Number of horse cars	1584	1794	1694	1662	1226	826	606
,, electric cars		47	337	469 (*a*)	1028	1346	1509 (*g*)
Total revenue miles run	15,431,758	16,573,831	17,665,360	17,462,572 (*b*)	17,498,660 (*c*)	18,669,809 (*d*)	19,240,486 (*e*)
Electric revenue miles	..	..	..	4,588,186	9,622,000	14,189,054	16,794,661
Percentage of expenses to earnings	82	82	77	74.4	70.8	68	66.44
Investment in electrics	..	85,270*l.*	312,132*l.*	..	1,188,890*l.*	1,572,334*l.*	..

(*a*) The long cars introduced at this time, and now almost exclusively used on the company's electric lines, are almost twice the size of the regular two-horse car.
(*b*) Electric mileage .. 26.27 per cent. Horse mileage .. 73.73 per cent.
(*c*) ,, 48.63 ,, ,, 51.37 ,,
(*d*) ,, 76.17 ,, ,, 21.83 ,,
(*e*) ,, 87.29 ,, ,, 12.71 ,,
(*f*) And 25 additional miles partially electrically equipped.
(*g*) And 103 electric snow ploughs.

(Population of Boston, 1890, 448,477.)

The decrease in the percentage of working expenses to gross receipts has varied almost directly in proportion to the introduction of electric plant. In 1888 and 1890, before the electric motors had been introduced, the percentage of expenses to earnings was 82 per cent. In 1890, as soon as the first outlying lines were electrically in operation, the percentage decreased to 77 per cent. In 1891, over one-fourth of the car-mileage being electrical, the percentage is again decreased to 74.4 per cent. In 1892, with nearly one-half of the total mileage run by motor cars, the percentage drops to 70.8 per cent. In 1893, over three-fourths of the entire system having been electrically equipped, we find the ratio of expenses to earnings only 68 per cent., and the statistics of 1894 show the present operating expenses to be 66.44 per cent. of the gross receipts. This reduction has been made, notwithstanding the fact that the additional investment required for electrical plant and apparatus had to be provided for, and that such part of the former rolling stock, buildings, horses, &c., as was rendered

useless or disposed of at a loss, had to be written off. Moreover, the introduction of heavy motor cars, and of a service higher in speed, required that the permanent way should be reconstructed in many places, and much heavier metals employed.

The adoption of electric motive power by the West End Street Railway Company practically established the economic value of that system of traction. Under the energetic management of Mr. Henry M. Whitney, its late President, every known method of mechanical traction was examined and tested to the fullest extent, regardless of the expense incurred by so elaborate an investigation. The supporters of accumulator traction and of systems employing sub-surface conductors, were given every opportunity to exhibit their practical value on the Boston lines under conditions of actual street-railway service. Many thousands of pounds were spent on experimentation by the Company, but no system successfully stood the test of commercial operation except the trolley-wire. In 1888 and 1889 Boston was the Mecca of every inventor, promoter, and company interested in traction improvements, and all were given a free hand and a fair field. It is improbable that so extraordinary a competition will ever again be witnessed, and no company of less financial strength, or with a more narrow-minded board of directors and executive, could have brought the contest to a successful issue. The prize offered was a grand one, for the decision of the West End Street Railway Company carried with it not only the extensive contracts for its own re-equipment, but the certainty that the system approved by it would be accepted as conclusively superior by the great majority of the tramways of the United States.

Within the first six months of the Boston trials, accumulator cars and conduit-contained conductors were hopelessly out of the race. The trolley wire and wheel had demonstrated an overwhelming superiority. The new system of mechanical traction was accepted throughout America.

The figures of the West End Street Railway Company, showing decrease in operating expenses proportionate to the introduction of electrical power, are amply borne out by the results attained in many other instances. Table X. shows that the same practical economy resulted from the equipment of the Brooklyn (N. Y.) line.

To fully appreciate the conditions under which this great advance has been made, it must be borne in mind that at the time when electric motive power was introduced, the permanent way and equipment of the street railways of the State were by no means in a satisfactory condition, and great

expenditure had to be incurred before they were placed in first-rate working order. Large sums were also disbursed in the necessary legal procedure to secure new franchises, or extensions of powers already granted. To secure necessary authorisation for the erection of aërial conductors, in the face of the strong prejudice against their use then obtaining, was a tedious and costly matter. Moreover, the first work done was in many cases experimental and defective, and the total cost of re-equipment greatly increased by the necessity for radical changes in the methods and designs originally proposed.

TABLE X.—Results Obtained by the Introduction of Electrical Motive Power on the Brooklyn City Street Railway.

Brooklyn City Railway Company for the year ending June 30.	1891.	1892.	1893.
Capital stock	1,200,000*l.*	1,200,000*l.*	1,800,000*l.*
Funded debt	457,800*l.*	785,000*l.*	758,000*l.*
Total net income	98,100*l.*	104,795*l.*	144,145*l.*
Total mileage of track	176	184	210
Electric track mileage	5.4	20	120
Number of passengers carried	73,700,000	78,500,000	83,196,302
Total number of cars	1549	1603	1680
Number of electric motor cars	20	76	413
Number of horses	5508	5587	4648
Ratio of operating expenses to receipts	77.5 p.c.	77 p.c.	73 p.c.

The first cost of installation and equipment has naturally varied widely, according to local conditions and necessities, and it is, of course, impossible to fix, even approximately, any average which includes such items as land, paving, &c., which can only be determined by the circumstances of each case. From a large amount of data, most courteously placed at the disposal of the writer by American street railway managers and contractors, it would appear that the following figures are fairly accurate:—

TABLE XI.—Cost of Electrical Motive Power Installation.

Initial cost of power-house, generating plant, car-shed, rolling stock, motors and their immediate accessories, per motor car equipped	£1,000
Initial cost of permanent way (exclusive of paving), rail-bonding, elevated conductors, wooden poles, insulation and suspension, per mile of single track	£2,000

The enormous carrying power of an electric road when called upon to meet the demands of heavy service is an interesting feature. The following

figures, given by Mr. Bowen, of the Chicago City Street Railway Company, show the work done by his electric line on "Chicago Day" at the World's Fair.

Fifty-one double-motor cars, 10 single-motor cars, and 73 trail cars were in operation over 26 miles of track. During the day 208,575 passengers were carried, and 11,271 car-miles run. The maximum output at the power-house was 17,000 amperes, and the average for 20 hours about 1,050. The minimum current registered was 750 amperes, and the average station pressure 540 volts. The coal consumed in the power-house amounted to 23 tons. The ratio of expenses to receipts on this line is approximately 40 per cent.

As showing the volume of business handled by American lines, it is worthy of notice that on that day the entire system of the Chicago City Railway Company, consisting of 98.21 miles of horse and 34.97 miles of cable lines, besides the electric railway above referred to, carried 1,003,650 passengers.

CHAPTER II.

PERMANENT WAY.

UNTIL a few years ago the track construction of American street railways was invariably greatly inferior to that employed in England. With the development of mechanical traction, better and more substantial road-beds were required, and heavier metals used. Many of the best American lines now compare favourably, as regards solidity of construction, with English lines.

TABLE XII.—GIVING PERCENTAGES OF FOREIGN MATTER IN STEEL RAILS (HAARMANN).

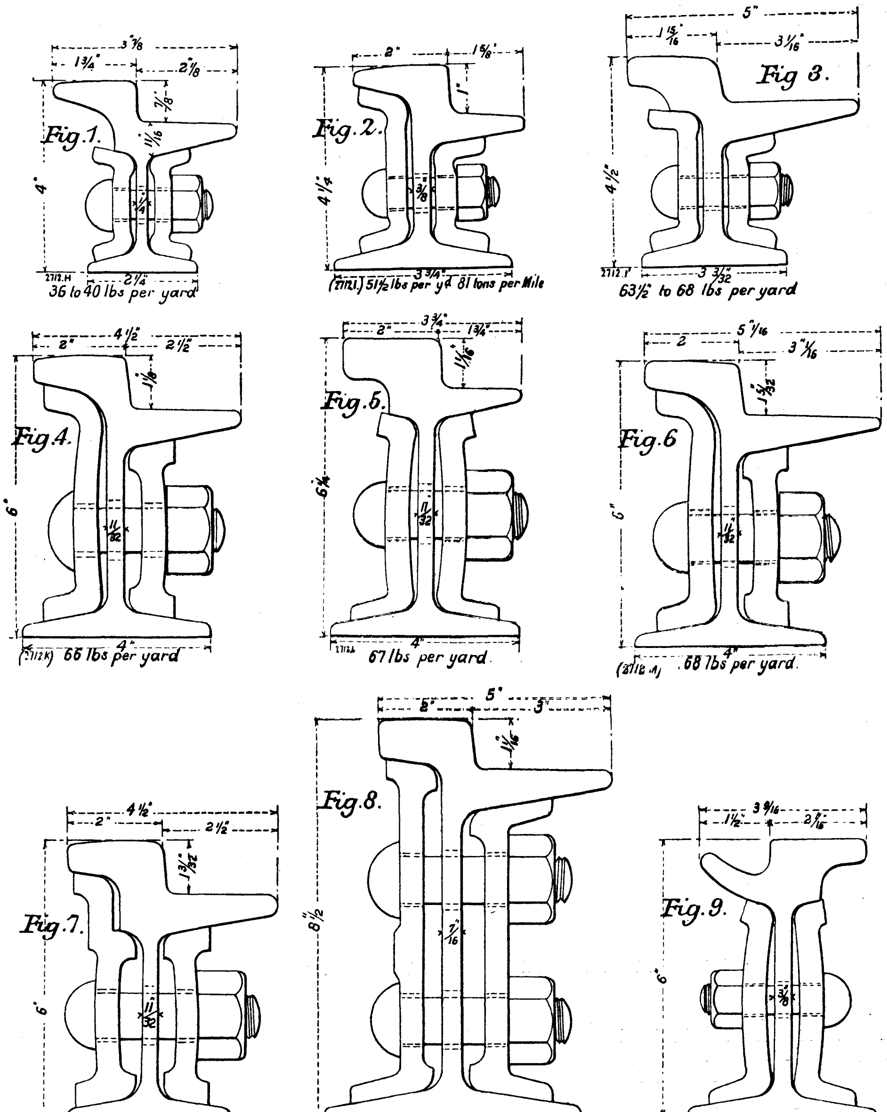
Silica	0.3 to 0.35 per cent.
Carbon	0.25 „ 0.35 „
Phosphorus	0.08 „ 0.10 „
Manganese	0.70 „ 0.90 „

According to Mr. Haarmann, the above Table gives the quantities of foreign substances which may be contained in steel used for rails. These average percentages should in no case be exceeded, and they correspond with the best present practice. By means of the Siemens process this result is easily obtained, but not by the Thomas process.

It is in the style of rail employed that American and English practice differ most widely. In American track-work the primary consideration (and in earlier times the only point apparently considered at all) is to accommodate the street-car wheel to the fullest extent—other vehicular traffic taking an entirely secondary place. In English practice the reverse may be said to be the case. Climatic conditions have naturally much to do with the type of rail employed. It would be well-nigh impossible to use the latest English narrow-groove rail in districts where snow and severe cold may be expected during many months of each year.

In country roads, and in the smaller towns, the T-rail is naturally used. In larger towns the step-rail (Figs. 1 to 8, see opposite page) is almost universally employed, and from the point of view of the street-railway operator, it is a nearly perfect rail. The larger cities, especially

those of the Atlantic seaboard, are slowly introducing the grooved rail, the groove, however, being much wider and deeper than that ordinarily employed in England (Figs. 9, 10, 11). Even where the grooved rail has been laid, it is not infrequent to find special rails used for curves (Figs. 12, 13, and 14),

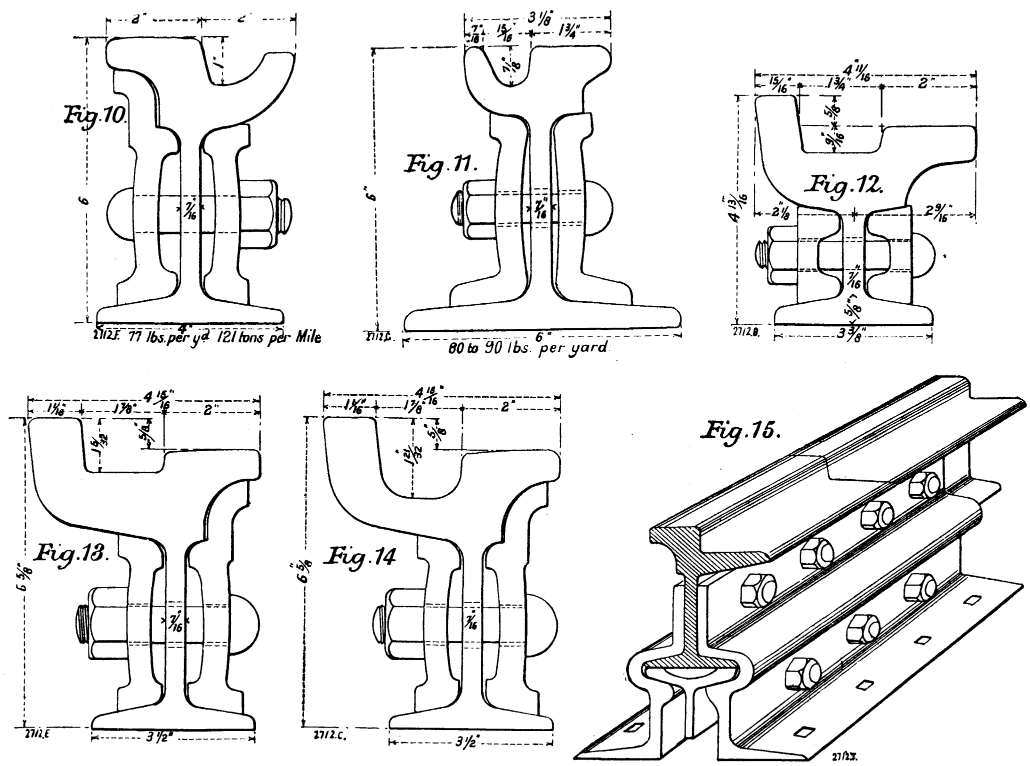


SECTIONS OF STEP AND GROOVED RAILS FOR STREET RAILROADS.

one side of the rail being much higher than the other. This enables the cars to take curves of very small radius at a comparatively high speed.

The conditions governing the construction of permanent way for a street railway operated by self-propelling cars, having a load of 5 tons or

more upon each axle, and running at a speed of from 10 to 25 miles per hour, differ widely from those which maintain where comparatively light horse-cars at slow speeds are to be employed. In the former case, the best permanent way, so far as smooth and easy operation is concerned, approaches nearly that of the steam railway, and it is naturally the endeavour of the electric railway manager to secure the greatest solidity of road-bed, a type of rail which is not open to being easily choked, and rigid joints. The joint shown in Fig. 15 has proved fairly successful.



American Grooved Rails and Special Sections..

A method of track construction which has attracted considerable attention, and which has been adopted to some extent on the Continent, is that known as the Haarmann Composite Rail, a section of which is shown in Fig. 16. A grooved rail is made up of two sections which are kept apart by means of distance pieces, the centres of which are about 20 in. apart. The joints of the two rails do not coincide, and the heavier of the two rails at the joint is cut at an angle. It is stated that a very much stronger joint is obtained and that low joints are practically impossible. The standard height of this rail is 160 mm. (approximately $6\frac{1}{3}$ in.). The maxi-

mum width of the groove formed by the two rails is generally 30 mm. (slightly over an inch). The total width of the bases of the two rails which rest on the concrete is 158 mm. (approximately $6\frac{1}{5}$ in.). The rails are connected by tie rods every 2.25 metres (a little over 7 ft.). The tie rods are connected to the rails by means of two bolts, and have a rectangular section of 60 mm. by 10 mm. (approximately 2.3 in. by 4 in.). In the latest instances where this track has been laid, the weight of track per yard, including tie rods, &c., has been over 200 lb. There is no doubt that the tendency on the Continent, as well as in America, is to use a type of rail which weighs from 80 lb. to 90 lb.

Track construction in large English towns is generally much more expensive than in America, owing to the requirements of the Board of Trade and the rules enforced by the Local Authorities. Table XIII. gives

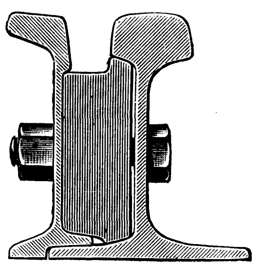


FIG. 16. HAARMANN'S COMPOSITE RAIL.

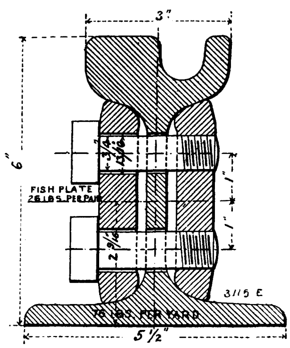


FIG. 17. BRISTOL TRAMWAY RAIL.

cost as estimated by Mr. Gordon L. Stevenson, Engineer of the South London Tramways.

TABLE XIII.—GIVING COST OF GIRDER RAIL CONSTRUCTION FOR 7-IN. PAVING, ACCORDING TO MR. GORDON L. STEVENSON.

	£	s.	d.
Rails, 112 lb. per yard = 176 lb. per mile, fishes and bolts, $12\frac{1}{4}$ tons per mile (no tie-rods), 1,760 yards, at 16s. 6d. ...	1,452	0	0
Excavation, lifting and carting way, 19 in. deep, 11 ft. wide, 3,406 cubic yards, at 3s.	510	18	0
Concrete, 12 in. deep, 11 ft. wide, 2,151 cubic yards, at 13s. ...	1,398	3	0
Watching and lighting	30	0	0
Total for the way	3,391	1	0
Paving, 11 ft. wide, 6,453 square yards, at 12s.	3,871	16	0
Total for the way and paving per mile, single line	7,262	17	0

Table XIV. gives figures supplied by Mr. Joseph Kincaid. In this instance the ground is excavated for a distance of about 12 in. below the level of the rails. The rails are held to gauge by iron tie-bars $1\frac{1}{2}$ in. by $\frac{3}{8}$ in. and 8 feet apart, notched on one end into the web of the rail and set to gauge by means of a nut and lock nut. The rails in this instance are 78 lb. per yard, 6 in. high, and 6 in. wide at the base, the web is $\frac{3}{8}$ in. thick, the base $\frac{1}{2}$ in. thick near the web, and tapering down to $\frac{5}{16}$ in. The total width of the head is 3 in., giving $1\frac{1}{2}$ in. of tread, and the groove is 1 in. in width. The rails are connected by $\frac{3}{8}$ in. iron fishplates, 15 in. long, with four $\frac{3}{4}$ in. bolts and nuts. The joints are further secured with $\frac{3}{8}$ in. steel sole plates 16 in. long and 9 in. wide

TABLE XIV.—Giving Cost of Girder Rail Construction for One Mile, Single Line, according to Mr. Joseph Kincaid.

tons.	cwt.	qrs.		£	s.	d.
122	11	2	steel girder rails, 78 lb. per yard, at £6	735	9	0
3	4	3	wrought-iron fishplates, $10\frac{1}{2}$ lb. per pair, at £7 ...	22	13	3
2	1	1	wrought-iron joint plates, $10\frac{1}{2}$ lb. each, at £12 ...	24	15	0
4	10	0	wrought-iron tie-bars, $15\frac{1}{4}$ lb. each, at £12 ...	54	0	0
1	0	0	bolts, nuts and washers, at £20	20	0	0
1,662 cubic yards excavation, at 2s. 6d.				207	15	0
846 cubic yards Portland cement concrete, at 15				634	10	0
1,760 linear yards laying the way, at 1s. 6d.				132	0	0
Total cost of way per mile, single line				1,831	2	3
4,376 square yards granite paving sets, including 1 in. bed of gravel, laying of grouting per mile, single line, at 7s. 6d. ...				1,641	0	0
Total cost of way and paving per mile, single line				3,472	2	3

Dummy points should not be used on electric tramways. Moveable points only should be employed. These should be exceptionally strong, and special boxes should be provided at each point with drains to the sewers, so as to prevent dirt and water accumulating in the points and blocking them. Great trouble was originally experienced in the United States, when electricity took the place of horse traction on tramways, owing to points suddenly giving way and crossings wearing out, causing heavy jolting of the cars and damage to the motors and equipment. In some Continental countries, and also on some English roads, rails laid down on iron or steel longitudinal sleepers have been adopted. Table XV. gives quantities and particulars of cost of such a line, and is taken from Mr. D. Kinnear Clark's work on tramways.

TABLE XV.—Giving Quantities and Cost of Construction for Permanent Way on Metallic Sleepers.

	£	s.	d.
Way, 151 tons, 1,760 yards, at 15s. 4d.	1,349	6	8
Bessemer steel rails, 58 lb. per yard, 91 tons			
Wrought-iron sleepers and clips, 36½ lb. per yard, 57 tons			
Wrought-iron fishplates, 2½ tons			
Wrought-iron bolts and nuts, ½ ton			
Excavation, 1,207 cubic yards, at 3s.	190	10	0
Portland cement concrete, 600 cubic yards, at 15s.	495	0	0
Cost of way	2,034	16	8
Paving, 3,670 square yards granite sets, at 10s.	1,835	0	0
Bituminous grouting, 3,670 square yards, at 2s. 3d.	412	17	6
Cost of paving	2,247	17	6
Cost of way and paving	4,282	14	2

The type of rail used on the new electric tramway at Bristol is of Mr. Kincaid's design. The section adopted is shown in Fig. 17. It weighs 76 lb. per yard, and has unusually heavy fishplates. It will be observed that no nuts are used; the fishplates on one side being tapped, and the bolts, which are ¾ in. in diameter, screwed into them. It will also be noticed that the fishing angle is less obtuse than is usually the case with tram rails. The groove for the wheel is an inch wide and ⅞ in. deep. No cross-sleepers are used, but the rails are bedded on concrete 6 in. thick, extending the full width of the tramway. They are connected by four cross-ties to each 30-ft. length. These ties are flat steel bars, 2 in. by ⅜ in., with two nuts at each end, bolted through the web of the rail.

With the extremely high rails (9 in. and 10½ in.) now used in America, weighing over 100 lb. per yard, having extremely massive fishplates, holding the rails together by means of twelve 1 in. bolts in a double row, and resting at both ends on wooden cross sleepers, extremely good joints are secured. Suspended joints seem most in favour. With animal traction, slow speed and light cars, it is possible to operate for long periods over defective track. Where motor-cars are employed, defective joints are rapidly pounded, so that not only is the permanent way injured, but the repeated blows inflict great damage upon the trucks, car bodies, and last, but not least, upon the motors themselves.

This has led to the nearly general adoption of the practice of butting the rails one against another, without leaving any room for expansion; and, indeed, should the rails have been laid in hot weather, so that when the temperature falls, spaces remain between the rails at the joints, thin sections of rail are forced in between them to fill up the interstices. This mode of laying is only used where the streets are paved, and the result obtained has been perfect joints. The only effect of expansion is noticeable in a slight thickening of the rails in summer. Of course, when the paving has to be removed, it must not be taken up on too long a stretch at a time, otherwise the spring of the rails might produce disastrous results. Boston, Philadelphia, St. Louis, Chicago, Brooklyn, &c., have parts of their roads laid in this way with the best results, the consequence being an entire absence of low joints.

To avoid the necessity of taking up the pavement whenever a rail joint is to be inspected, "joint boxes" are often used. These are made of heavy cast iron, with removable corrugated iron covers. They are set outside the track at each rail joint and spiked to the ties or sleepers. If the latter settle, the boxes become useless, for the pavement must be removed and the boxes tamped up to level. For tightening up fish-plates, and enabling the electrical connections of the rails to be properly attended to, these boxes are of great service.

In all American roads the points and all special work are of steel, and the large mills pay great attention to this work. Crossings and turnouts of the most complicated nature are often required (see Fig. 18), owing to the enormous extent of the street-railway lines. In some roads the special work is so frequent and the traffic so heavy, that parts such as points and crossings have often to be renewed.

In T-rail special work, the inside rail on curves is generally guarded by a second rail bolted to it, the two rails being held apart by cast-iron filling pieces. The space between these rails is afterwards filled with cement to within an inch of the top, so as to cause as little obstruction to traffic as possible. The guard rail is slightly elevated above the running rail. Frequently rails are used in paved streets of insufficient height to admit of a paving block between the ties and the head of the rail; when this is the case, the difference in height has to be made up by the use of chairs. Where these are used, a longer time is required to lay the line than where the method of direct spiking to the ties is employed.

At intersections, the construction must be such as to guide the cars in

whatever direction required without any other external assistance than the moving of the tongues in the switches. In places where a groove is to be crossed that would cause the car to run unevenly, the floor should be raised so as to give a bearing on which the flanges may run. On double-track lines the distance between tracks is usually from 4 ft. to 5 ft., but in order that cars may pass one another on the curves, and not be obliged to wait upon each other at the ends of curves, this distance is generally increased at such points to 7 ft. or 8 ft. to provide ample clearance. This extra width is obtained by striking the curves from different centres. The practice in Montreal and Toronto is to make the inner and outer curves of

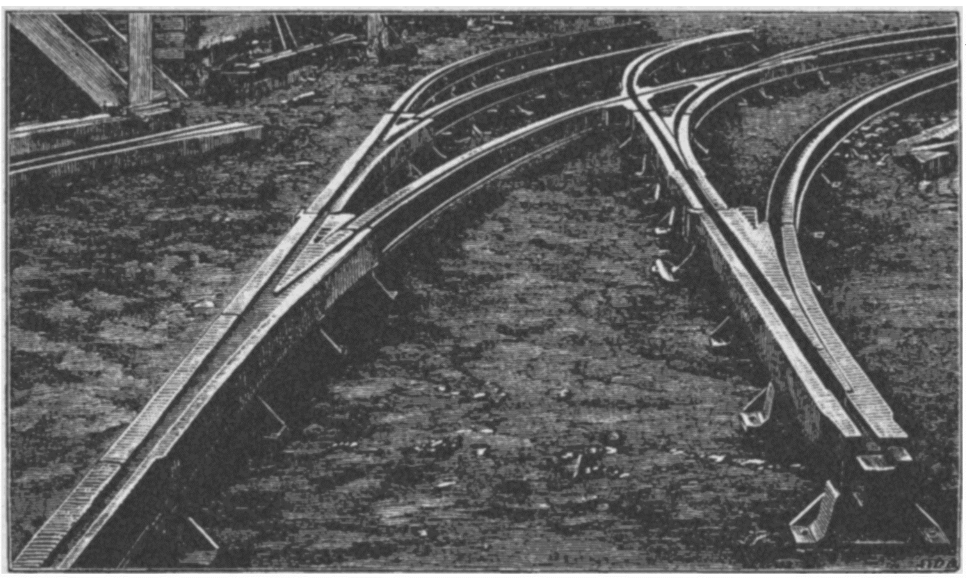


FIG. 18. TYPICAL CROSSING AND TURNOUT.

the same radius when the apex angle is approximately 90 degrees, but when the angle varies greatly from a right angle, the outer curve is made sharper than the inner when running round the obtuse angle. Passing sidings are used on single-track lines. They may be divided into two classes, diamond and throw-over sidings.

In the diamond siding the track diverges like a **Y** at either end, so that the centre line between the tracks in the sidings is in line with the centre line of the single track. This is the form usually adopted on single tracks running through narrow streets. If it is desired that cars should run either to the right or left at these points, the switches of the sidings must be provided with moveable tongues, but if the cars always run in the same

direction, they may be guided in the direction required by a moveable tongue held to the proper side by a spring, so that a car facing a switch is always guided to the same side, and a car trailing it compresses the spring and passes on, the tongue of the switch falling back to its proper position. This guiding of the car in one direction, however, may be provided for much more simply by means of a blind switch. One side of the switch is straight and the other is curved; the front of this switch coincides approximately with the end of the curve of the switch, whilst the curve to the opposite side begins near the back of the switch. In the throw-over siding one track is continued straight through, while the other is thrown over to one side of it. If cars are to be run on either side, moveable tongue switches are necessary. If the cars always keep to the same side, the tongues must be provided with springs, or blind switches used. The radius for the curves of passing sidings in Montreal and Toronto is 300 ft. to inside gauge lines.

Crossovers are used on double-track lines for transferring cars from one track to the other, and are placed at the termini of regular routes.

Crossovers and turnouts should change the direction of the car's motion from one line into another with the least amount of resistance possible. In Montreal and Toronto these have 75 ft. radius curve and about 25 ft. of tangent; this gives a crossover of about 60 ft. between extreme ends of switches. Crossovers and turnouts are said to be either left or right hand according to the direction in which they curve from the track, as seen from the switch when looking towards the cross.

Having laid down the routes of a street-railway system the special work required becomes apparent. It is most important that curves likely to be required in a few years should be laid, if at all possible, during original construction, as the addition of a single curve to an intersection in some cases necessitates the reconstruction of the greater part of the whole intersection.

A careful survey must be made of the intersection of streets requiring special work, and all measurements of lines and angles taken which are necessary to plot with the greatest accuracy the centre lines of the proposed track, together with the street and curb lines.

These measurements are plotted to a suitable scale, and the most suitable radii for the required curves determined, usually from 40 ft. to 75 ft. An improvement may be introduced by making the switches at the ends of curves of a longer radius than the main part of the curves, such as using

75 ft. radius switches on 45 ft. radius curves. This eases the curves for 10 ft. at each end, and meets all practical requirements.

These curves may appear very sharp to steam railroad engineers, yet there is a case of a 50 ft. radius curve on a trestle being used on a steam railway, and operated successfully at a speed of from 8 to 10 miles an hour (U. S. Military Railway, Petersburg, Va.). The Manhattan Elevated Railway, in New York City, has curves of 90 ft. radius. Of course, in tramway construction it is impossible to super-elevate the outside rail, and where possible in these cases, guard rails are put in. In light railway construction, where high speeds are attained, super-elevation becomes necessary; and the following Table gives the super-elevation usually adopted on the light railways in Belgium.

TABLE XVI.—GIVING SUPER-ELEVATION OF TRACK ON CURVES.

Radius in feet.	Speed of 6 miles an hour.		Speed of 19 miles an hour.	
	Meter Gauge.	Standard.	Meter Gauge.	Standard.
	in.			
6,000	...	...	0.156	0.195
4,500	...	...	0.195	0.273
3,000	...	...	0.273	0.390
2,700	...	...	0.312	0.468
2,400	...	0.039	0.351	0.507
2,100	...	0.078	0.390	0.585
1,800	...	0.078	0.468	0.663
1,500	0.039	0.078	0.546	0.780
1,200	0.078	0.117	0.663	0.975
900	0.117	0.156	0.897	1.287
600	0.156	0.234	1.365	1.989
450	0.195	0.312	1.833	2.613
300	0.312	0.429	2.730	3.939
225	0.390	0.624	1.638*	2.340*
150	0.585	...	2.457*	—
120	0.741	—	—	—
90	1.014	—	—	—

* Speed reduced to 12 miles an hour.

Having completed the calculations for an intersection, the detail drawings for each piece are made and sent to the shop, together with a print showing the whole intersection with the distinguishing marks of all pieces and lengths of the connecting rails. A drawing is also made for assembling the work in the streets, showing all necessary measurements for laying out the work, together with the position and marks of the various pieces.

In a tongue switch the long rail has to be properly curved and slotted or bent for the tongue to fall into place. The tongue is made of hammered steel, and the turned pin is shrunk in; this is dropped into place, and all measurements checked before being considered ready for the track.

In the blind switch and mate, one rail is planed so as to leave a long notch on one side, while the other rail is planed to a point which fits into the notch. The two are strongly bolted or riveted together, and sometimes finished on a planer.

The curve crosses have usually two pieces of rail, one of which has the upper part so shaped at the crossing point as to allow a second one to drop down on the first, and fit accurately into the place allowed for it; while the second has the lower part shaped so as to allow the first rail to pass through, the two rails jointing neatly into one another. Great care is necessary in the fitting to have the angles of the intersection exactly as required. In order to obtain the correct angle, the drawing shows the spread at a fixed distance, with the deflections of the curves at that point; so that this distance is measured along the rails from the intersection point, and the deflections marked from the gauge line. The spread is then measured between the points so marked.

An intersection should always be assembled as a final check before shipping.

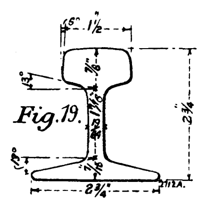
To know exactly what are the pieces used and which have to be replaced, many companies have large drawings showing a plan of their whole system with every piece of special work employed on it numbered, so that by referring to a table on which each of these numbers and what it refers to is noted, any special work that has gone wrong, and the particular piece to replace it, can at once be known.

The use of the T-rail in America has, on the whole, given great satisfaction. The groove on the inside—in wood, brick, or stone-set paving—is formed by special blocks laid next the rail, having their inner corners cut off. In the case of asphalte pavement, the groove is made by a car being run over the fresh asphalte paving while it is yet soft.

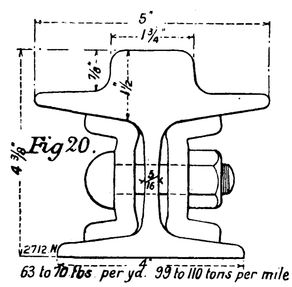
The centre bearing rail (Fig. 20) has also many warm supporters among street-railway operators, as being one of the easiest running forms.

Where grooved rails are used in America, the grooves are not only much larger than in England, but the outside wall of the groove is inclined about 45 deg. on the perpendicular, thus allowing the dirt which

accumulates in the groove to be pushed out by the flange of the wheel, instead of the latter mounting up and riding on it, as is the case with dirty grooves having vertical sides (Figs. 9 and 11). With mechanical traction, but especially with electrically propelled cars, the greatest care is given to designing and constructing curves, for the conditions differ widely from those where animal traction is employed, and the car can be pulled in either direction desired. The general practice is to employ spiral transition curves; the straight track must be a perfect tangent to the initiatory curve. For the ordinary four-wheel cars, having 6 ft. wheel bases, the radius of a curve should not be less than 35 ft. Some engineers lay the rails on curve to gauge, others allow half an inch to make the passage of the wheels easier. Special grooved rails used in curves are shown in Figs. 12, 13, 14.



T-Rail.



Centre Bearing Rail.

Table XVII. is taken from the rules laid down for the construction of the narrow gauge light railways in the kingdom of Saxony.

TABLE XVII.—Showing Widening of Gauge on Saxon Narrow Gauge Light Railways. Gauge, 750 millimetres.

Radius.	Widening of Gauge.
300 metres	5 millimetres.
200 ,,	10 ,,
100 ,,	15 ,,
75 ,,	20 ,,

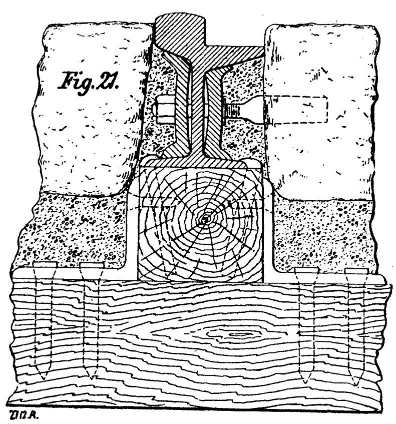
It has been found that all steels do not give equally good results as regards wear and tear, and it is now the universal practice in calling for steel rails to specify that the rails should be made of the best Bessemer or Martin Siemens steel.

The following figures give the cost per mile for a double track laid in a paved street where no extraordinary difficulties have to be encountered, the foundation being of gravel or broken stone :

TABLE XVIII.—COST OF ONE MILE OF STRAIGHT DOUBLE TRACK, LAID WITH 78 STEP-RAILS, 30 FT. LONG. (AMERICAN.)

	£	s.	d.
704 rails, including channel points, chains, and spikes ...	2,640	0	0
4224 sleepers, $2\frac{1}{2}$ ft. centres	380	3	$2\frac{1}{2}$
Labour, excavating and laying, including teams and superintendence...	633	12	0
1024 cubic yards of gravel	226	16	0
352,000 granite blocks	1,971	4	0
Labour of paving...	3,598	4	0
Total cost per mile of double track	9,449	19	$2\frac{1}{2}$

Fig. 21 shows a type of construction greatly favoured by the West-End Street Railway of Boston several years ago. It allows of



RAIL SECTION, WEST-END STREET RAILWAY, BOSTON.

lower and lighter rails being used in paved streets. The rail weighs 78 lb. per yard, and the cost of the track per mile (exclusive of paving) was £2,200. As shown, longitudinal wooden stringers are employed, and are fixed to sleepers by means of short angle irons. The rail, having a 3 in. base, and being 4 in. high, is fixed by spikes to the stringer. So far, this construction has been very satisfactory, although at present, when new tracks are laid down, a construction nearly identical to that in Philadelphia is employed. In some cases, when the soil is soft or marshy, instead of laying the ties or sleepers on a layer of broken stone or gravel, they are laid on a 6 in. bed of concrete. Such a construction, otherwise nearly identical to the type just described, is used on some of the Pittsburgh roads.

The electric street railways in Philadelphia are of very recent origin, although that city is one of the greatest tramway centres of the United

States. The greatest possible trouble has been taken to make them as perfect as possible in every way, and their track construction is amongst the best in America.

The rails weigh 90 lb. to the yard, are 9 in. high, and of the step-rail type, Fig. 22. They are laid on wooden ties, 3 ft. between centres. On each tie are steel tie-plates, 6 in. by 10 in. by ⅜ in., upon which the rail rests. It is attached to the ties by means of three 5 in. by ½ in. hookhead spikes. Tie rods, 1½ in. by ⅜ in., at distances of 6 ft., and having ¾ in. round ends are also used. At each joint, and under the ties, a longitudinal tie is placed, which takes in the joint tie, and one on either side of it. The joints are made by very strong 8-bolt fishplates, 27 in. long, the bolts being

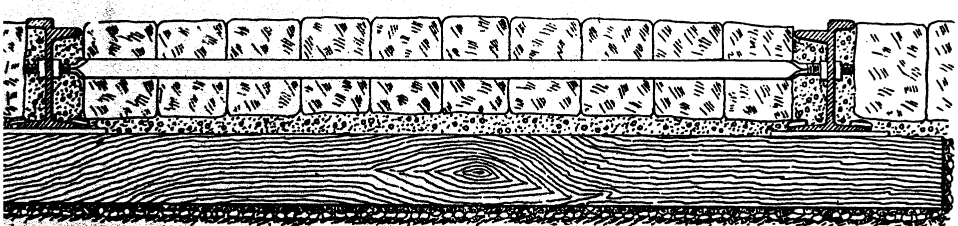
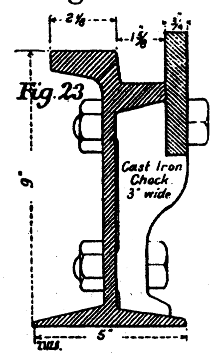
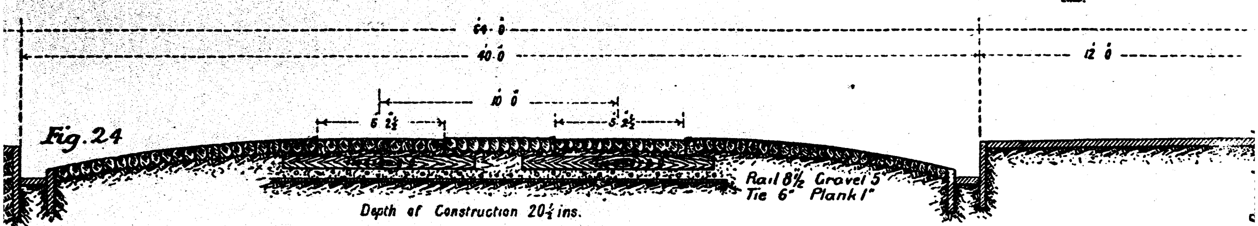


Fig. 22. Straight Track Section.



Street Railway Permanent Way, Philadelphia.



Street Railway Permanent Way, New Orleans.

⅞ in. with nuts and lock washers. On curves, special guard-rails are used, of which Fig. 23 shows a section. A ¾ in. steel bar, held in position by a cast iron chock, is bolted to the inside of the step rail, out of the inside flange of which a piece is cut, thus forming a groove. This guard rail, when worn, can easily be renewed. The ties rest on a layer of gravel or broken stone, about 4 in. deep, and brought up to a level with the top of the wooden ties or sleepers. Over the broken stone an inch of rough sand is spread, on which the paving stones rest. This construction has, so far, given every satisfaction.

The track construction employed at New Orleans, see Figs. 24 and 25, consists of 8½ in. girder step-rails, weighing 100 lb. per yard. The fish-

plates have twelve 1 in. bolts to keep them in place, six in a row. The ground being very wet and spongy, the following special construction is resorted to: The ground is excavated $20\frac{1}{2}$ in. approximately, a flooring of 1 in. cypress planks is then laid, and on this floor a 6 in. layer of gravel is put down. On this the 6 in. by 8 in. by 8 in. ties are laid, to which the rails are spiked.

The examples given so far have only shown step-rail construction, which is the favourite in the Eastern States. In the west, although the step-rail is also used, it is the T or Vignoles rails, which is rising in favour. It may be also remarked that in many large western towns the streets have, within the last few years, been laid with asphalte, and are in a very good condition.

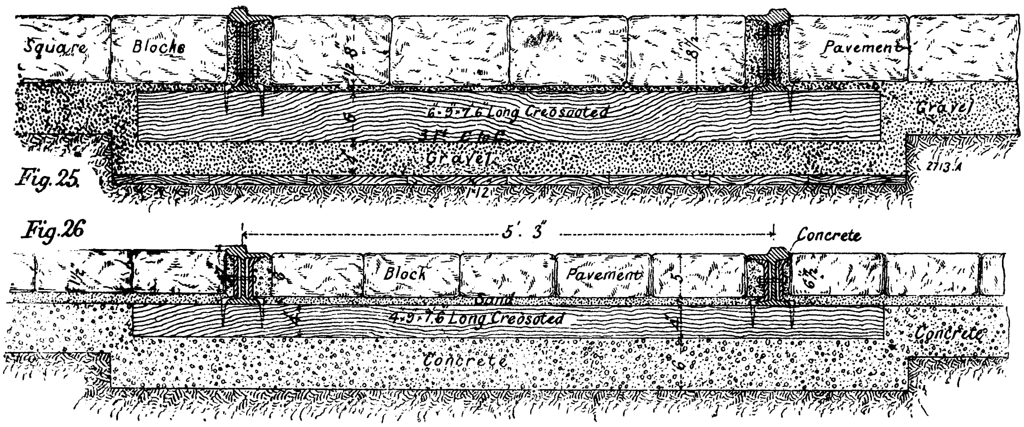
At Denver, the capital of the State of Colorado, 60-lb. T-rails, 4 in. high, on 6 in. by 8 in. wooden sleepers, 21 in. between centres, are used, laid on cement concrete foundations 6 in. deep under sleepers. This foundation is carried up above the ties except for a space averaging 10 in. in width directly under the rails. The concrete foundation is covered with a Blake asphalte paving, 3 in. deep. The following are the estimated quantities and cost per mile of single track:

TABLE XIX.—Quantities and Cost of T-Rail Construction at Denver, Col., U.S.A.

Track Construction with 60 lb. T-Rail.	Cost per Mile of Single Track.
$84\frac{3}{10}$ tons of steel rails (including freight, inspector, and hauling) ...	£730
10,800 lb. angle bars (30 lb. each), including hauling ...	44
1,150 lb. track bolts ($\frac{3}{4}$ in. by $3\frac{1}{2}$ in.), including freight and hauling ...	7
Nut locks ...	2
3,017 hewn red spruce ties (including hauling and inspection)...	343
6,050 lb. railway spikes (5 in. by $\frac{9}{16}$ in.), including freight and hauling	31
360 bonds placed complete ...	18
360 cast-iron joint boxes...	37
2,080 cubic yards excavation (trench 8 ft. wide 16 in. deep), all hauled away ...	129
Track laying, including blocking ...	207
Total ...	£1,548
Paving.	**Cost per Mile of Single Track.**
4,400 square yards Blake asphalte (7.5 ft. wide, 3 in. thick) ...	£1,632
36,178 cubic feet cement concrete ...	1,124
25,700 ft. lumber (2 in. by 14 in. pine) ...	74
Carpenter work, nails, hauling ...	15
Total cost per mile of single track ...	£4,393

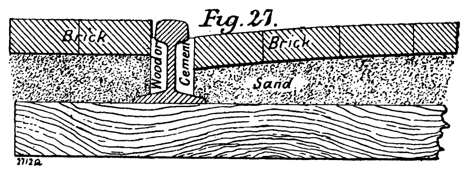
In San Francisco the newest electric road uses 90 lb. T-rails, 2 in. high, spiked to wooden cross sleepers, 3 ft. between centres, and iron tie-rods 6 ft. between centres. The rail had to be so high in order to allow room for the paving alongside of it. The sleepers were, in some instances, laid on concrete, and in others on broken stone.

At Des Moines, brick paving is used to a large extent (Fig. 27),



TRACK CONSTRUCTION AT NEW ORLEANS.

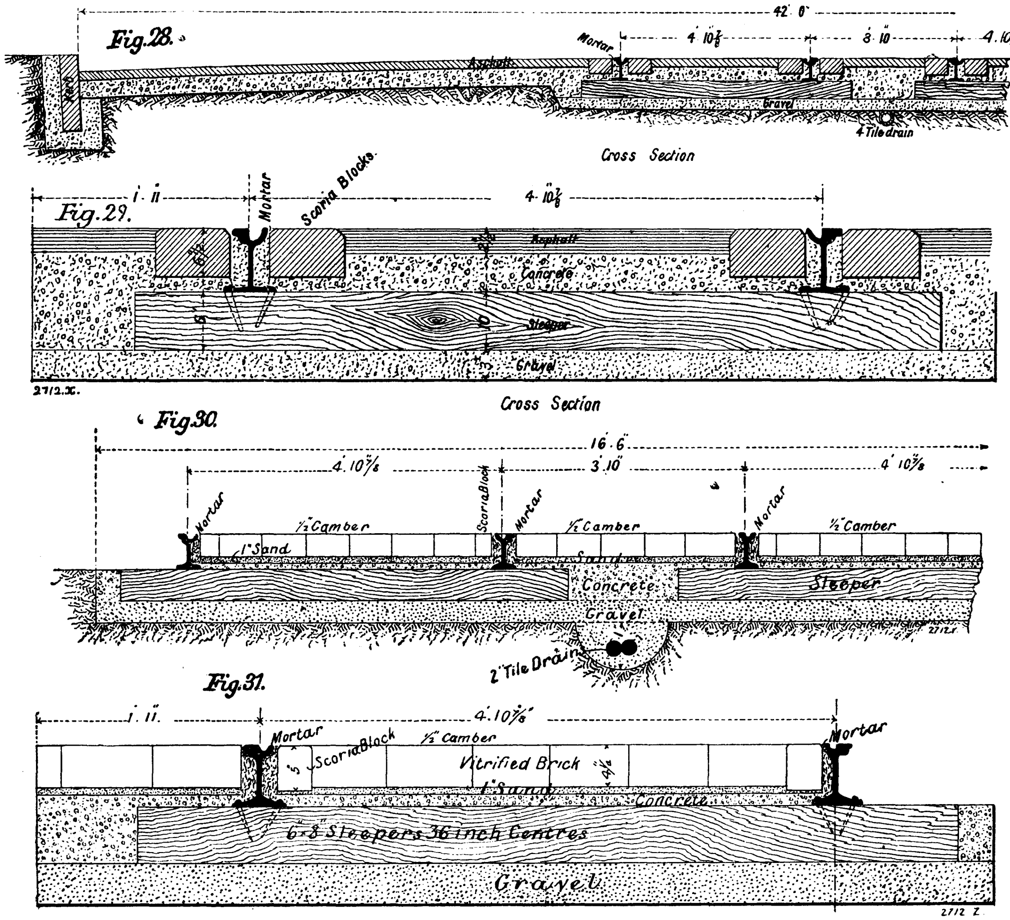
brought up flush to the head of the rail on the outside. On the inside the three bricks nearest the rail dip slightly, so as to allow room for the flange of the wheel to pass. The space under the head of the rail is filled with either wood or cement. The city authorities are extremely well satisfied with this mode of construction.



BRICK PAVING AT DES MOINES.

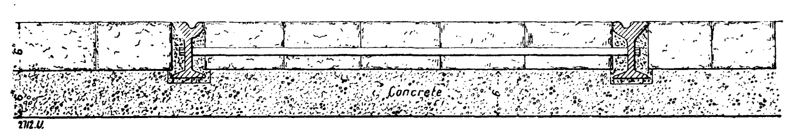
In Canada the track construction adopted is much more similar to that generally used in England, and is of the most substantial kind. The rail employed by the Toronto Railway Company is a $6\frac{1}{2}$ in. steel girder rail, weighing 70 lb. to the yard, and having a base $4\frac{1}{2}$ in. wide. The rails are laid on wooden ties, 3 ft. between centres, and the ties are laid upon a 4 in. bed of gravel. The pavement has been laid upon a concrete foundation,

well tamped underneath the rails, giving them thus a continuous bearing surface. The pavements at present in use are asphalte (Figs. 28 and 29), cedar block, cobblestone, and macadam. It is intended to replace the wood



Track Construction at Toronto.

Fig. 32.



Track Construction at Montreal.

by brick pavements, in many cases. Figs. 30 and 31 give sections of the proposed alterations.

At Montreal the construction is similar to the best English practice (Fig. 32). The girder rails are $6\frac{1}{2}$ in. deep, weigh 72 lb. per yard, and were

furnished by Dick, Kerr, and Company. They are laid directly on a 6 in. concrete foundation. The rails are tied together with iron tie-rods, and each side of the web of the rails is filled with cement grout mortar, in the proportion of one to one, to the width of the rail. The paving used is wood and stone, grouted with cement. The girder step-rail is being abandoned to a large extent in cities, and is being replaced by grooved and T-rails. Grooved rails are by no means as favourable to mechanical traction as T-rails. The question whether the latter can be used in paved streets and be as satisfactory to the public in general as the grooved rail has been very much discussed of late in the United States.

The American Street Railway Association appointed a special committee to examine into this question, and their report was presented at the Convention held at Atlanta, Georgia, in October last. The use of the T-rail was strongly recommended. Asphalte or macadam can be paved as easily to a T-rail as to any other. The pavement should be laid flush, and room should be made for the flange by running an extra heavy car, having a larger flange than the ordinary street car, over the track before it is opened for traffic. It has been found that a track so laid presents no more obstacle to driving than the grooved rail.

CHAPTER III.

THE RETURN CIRCUIT.

THE question of securing a sure and easy path by which the electric current, which has done its work in the street car motors, can return to the power-house and generators, is of extreme importance.

The earth, which in accordance with telegraphic practice, was supposed to have no resistance in the early days of electric roads, proved to have a very appreciable resistence. The electric current, therefore, tried to find an easier path by going through any metallic conduits which might lie in proximity to the track. The fall of pressure or voltage, at points of the line furthest from the power-house, caused a great waste of power. Not only the telephone companies, but the water and gas companies as well, soon became alive to the fact that heavy currents of electricity were circulating through their cables and pipes.

A thoroughly good connection between the rails and the switchboard at the power-house proved necessary to avoid rapid corrosion both of rails and of metallic conduits in the neighbourhood.

This connection should be of ample current capacity to accommodate such part of the return current as is not carried by return feeders. In one very old American plant which the writer visited, these connections were so poor that the ground in close proximity to the station was actually warmed by the return current. In this case there were no return wires, but only ground-plates at the station. This, besides meaning rapid wasting away of the rails, caused great loss of power due to the energy wasted in forcing the return current through the earth.

A good illustration of bad bonding and return connections, was the electric road built and equipped in 1887 in Richmond, Va., one of the first practical trolley roads built. On one line in that city, the fall in voltage was at first over 250 volts, which meant a loss of over one-third of a horse-power per ampere used. Nowadays, the fall of voltage on a line is generally kept within 10 per cent.

It is now recognised that an earth return for an electric road is a great mistake. The rails alone should be relied upon, and all possible precautions taken to minimise the current going to earth, by good and heavy bonding, and perhaps by dipping the rails and fishplates in tar or asphalte, or in the well known "P and B" preservative compound, as is done with gas and water mains.

It is evident that in city streets the ground is impregnated with ammonia, salt, and gases of all kinds. The soil is usually moist, and forms an excellent bath for electrolytic decomposition, the water, gas, and sewer pipes acting in some parts of an electric line as anodes, and in others as cathodes. Thus, in some parts, the pipes are corroded, and in others the rails are eaten away.

If W = weight in grammes deposited,
C = current in amperes,
T = time in seconds,
Z = electro-chemical equivalent,
Then W = C T Z.

Let us take, for example, a mile of single track in either Washington Street or Tremont Street, Boston, where there would be an average of at least 50 cars to the track-mile. The average current per car for 12 hours may be taken as 24 amperes. Therefore, in one year we should have: $50 \times 25 \times 12 \times 365 = 5{,}475{,}000$ ampere-hours per year per single mile of track.

If this total amount of current were to return solely by the earth, the iron dissolved would amount to approximately 3.8 tons per single mile of track per year, or if 30-ft. rails were used, to about 24 lb. per rail. This is, of course, never realised in practice, and this example is simply given to show what electrolysis might do.

To diminish the chances of electrolysis, and to do away with the losses caused by the resistance of the earth, the electric railway companies at first connected their lines to all the gas and water pipes they could reach. This caused a great rise in potential, very favourable to the efficiency of the line. It was, however, very soon found that water and gas pipes and lead-covered telephone cables were deteriorating most rapidly, and the electric railway companies were held liable for damage done.

The only method that had been adopted for bonding rails up to that time was copied from that generally in use on the steam railroads, which utilised their rails as a return for the electric current working their signals.

This consisted in soldering a thin iron wire to an iron rivet at each end of each rail, driven into the foot of the rail.

The following is a sample specification of the inefficient method of bonding used in early electric railway work :

"Each rail shall be connected to the following by two bonds made of No. 4 galvanised iron wire, each end of which shall be brazed to a $\frac{9}{16}$ in. Norway iron rivet; both of the bonds shall be separately connected with a No. 0 galvanised iron wire by means of No. 4 galvanised iron wire connections. Ground plates shall be placed at about 1,000 ft. apart. They shall be buried not less than 8 ft. in the ground; they shall be of galvanised sheet iron, 2 ft. square and $\frac{1}{8}$ in thick, bent round in the shape of a spiral."

This old practice has now been entirely abandoned as faulty, and the earth is no longer relied upon to carry the return current. Mr. T. H. Farnham, in an interesting paper read before the American Institution of Electrical Engineers, goes at great length into the damage done to cables and pipes laid in the neighbourhood of electric roads.

The alarm was first given at Boston, where a very large number of electric cars have been running since 1888, and where no efficient method of bonding had been resorted to. Early in 1891 some lead-covered telephone cables removed from wooden conduits in Boston showed very marked signs of corrosion, which, however, was entirely local. This result was at first attributed to the action of acetic acid contained in the wooden conduit; but, as the corrosion was so severe, and located in spots only, Mr. Farnham was led to conclude that it was more likely due to electrolytic action from the railway current.

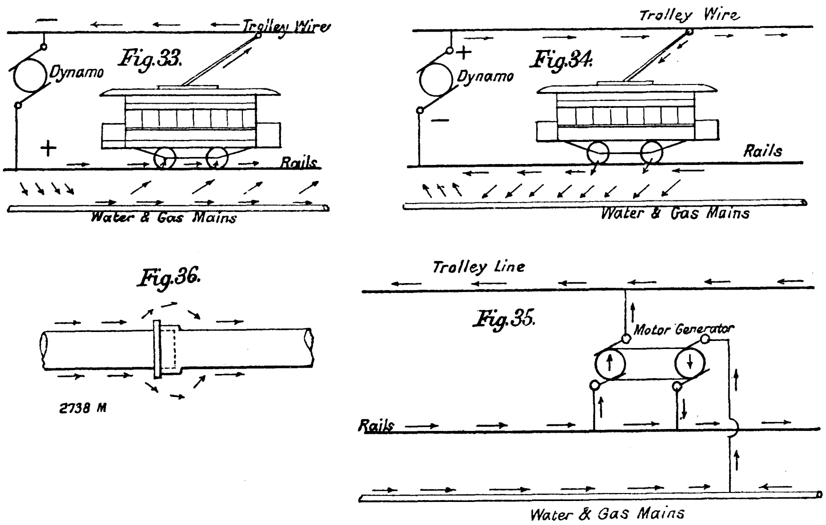
Measurements made at the manholes, between the cables and the earth near the cables, showed that within a radius of 2,000 ft. from one of the power-houses the cables were negative to earth, ranging from zero to two volts, but outside this neutral line they were positive to earth from zero to 12 volts. This prevailed until a point near a second power-house was reached, when again a neutral line was passed, and they became again more and more negative to earth. At the time these measurements were made, the railway had the positive poles of the generators connected to the rails and earth, and the negative to the trolley wire. The zone where the cable was positive to earth may be considered a dangerous one. Wherever telephone cables or water or gas pipes are negative to the earth, the current goes from the rails and earth to them; where they are positive the current leaves them for the rails. Corrosion takes place at all points where the

current leaves the metal (Figs. 33 and 34). It follows that by connecting the negative pole of the dynamo to the rails, the area where corrosion of pipes is likely, is restricted to the neighbourhood of the power-house.

The suggestions made to obviate this destructive action of the electric current were as follows:

1. To remove all cables from the wet bottoms and sides of manholes. This would not have been a remedy, as the action at the mouths of the ducts would have still continued.

2. That the telephone cables be connected to ground-plates in the manholes, so as to transfer the electrolytic action to the plates. This experiment was tried on a large scale, but did not prove a remedy, the



Diagrams showing Electrolytic Action of Return Circuit.

voltage between the cables and a point on the earth a short distance away being nearly the same as before the earth-plates were used.

3. Professor Elihu Thomson proposed the use of motor generators operated by the railway current, the secondary being used to reduce the potential in the telephone cables and pipes to zero with respect to earth and rails. This plan was not tried, as it would involve great expense (Fig. 35).

4. Insulating the telephone cables and pipes from earth. As some of the worst cases of corrosion occurred where the cables were painted with asphalte, taped and braided, this was not tried again.

5. Breaking the metallic continuity of the cable sheathing or pipes was proposed. This would cause a difference of potential between the several sections tending to cause electrolytic corrosion at one end of each section,

the resistance of the joint causing the current to leave the pipe or cable at a joint, go through the earth, and rejoin the conduit at the other side of the joint (Fig. 36).

6. It was proposed to alternate the railway current frequently. To do this in a large railway system would prove extremely difficult, and reversing once a day would only cause corrosion in two places instead of one.

7. The engineer of the West End road made two suggestions which, combined, have proved fairly successful. He proposed to connect the negative pole of the generators to earth, and to run out large copper conductors from the negative side of the switchboard connected to all pipes and cables which were in the dangerous zone, *i.e.*, where the pipes were found positive to earth. The first reversal of connections caused the dangerous zone to be restricted to the neighbourhood of the power-houses, where it could be dealt with, and the running out of copper wires connected to the mains in the dangerous zone prevented the passage of the current through the moist earth on its way back to the generators.

These suggestions have been adopted in Boston and throughout the United States with the best results.

The West End Railway Company of Boston has now special workmen who go with the gas and water construction gangs to all places where mains are being laid within the dangerous belt, and connect such pipes, by means of copper wires soldered to them, with heavy copper cables returning directly to the negative terminal of the switchboard, without any connection either with the rails or return circuit feeders at intermediate points.

In Boston this dangerous belt nowhere extends more than 4,300 ft. from the power-house, and in some directions only 2,000 ft., so that the cost of running out large copper cables, although heavy, is not prohibitive. As the joints of the gas pipes present a greater resistance than the pipes themselves, owing to the red-lead and other substances used in making joints, the current has always a tendency to leave the gas pipes and jump to the nearest water pipe—which is a better conductor—thus causing corrosion of the gas pipes at the point where the current leaves them. To diminish this danger, gas pipes are now connected, wherever possible, by means of soldered copper conductors to the nearest water pipes.

In other towns the damage to water and gas pipes was observed soon after the installation of electric roads which had badly-constructed return circuits and heavy traffic.

The corrosion of water and other pipes in the City of Brooklyn, in some instances proved serious. The report of the Board of Electrical Subway Commissioners of that city shows the gravity of the damage that was occasionally done. In one case, an iron water pipe was perforated and pitted with holes in 30 days (see Fig. 37, reproduced from photograph). Telephone cables and gas pipes were also badly injured. Although these cables had been laid in pitch and were contained in a conduit, this protection proved ineffective against corrosion. This committee also emphasised the fact that bare supplementary return wires laid between the rails were absolutely useless, and that, instead of using them, all the copper should be put into rail bonds, and insulated return feeders used where necessary.

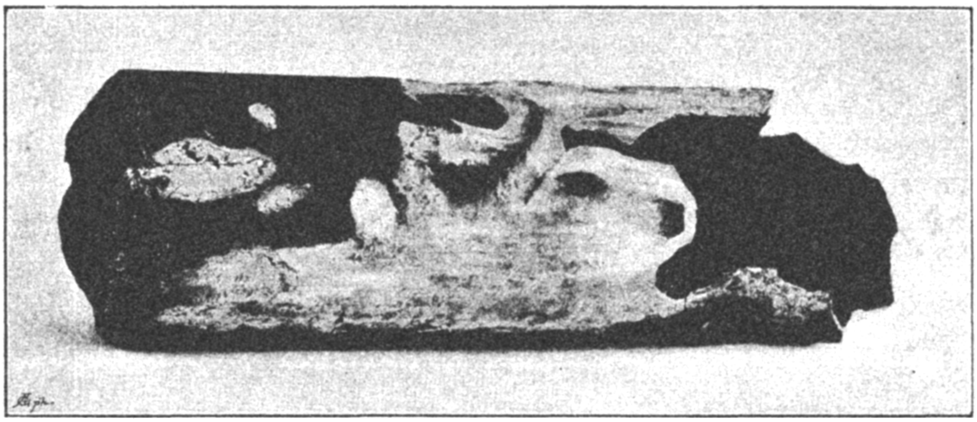


FIG. 37. PIPE CORRODED BY ELECTROLYTIC ACTION OF THE RETURN CURRENT.

Professor Jackson, of the University of Wisconsin, has made some very exhaustive and interesting experiments to find out what actually occurs in the ground, under the conditions brought about by the operation of electric street railways, and what occasioned the rapid corrosion of water, gas, and other mains observed in some American towns where electric railways were installed. Some persons have assumed that the corrosion was solely due to the chemical action of ammonia, saltpetre, leakage from gas mains, &c., in the earth; others that it was entirely due to electrolytic action.

The electrolytic action of the current may take place in two ways:

1. By direct electrolysis of the iron where the current leaves it.
2. By the electrolysis of chemical compounds held in suspension in the

water in the soil, which sets up secondary chemical reactions on the electrodes.

Where the electric current leaves a water-pipe at a joint, the pipe is the anode or positive plate. The soil surrounding it is the electrolyte, and the rail is the cathode or negative plate.

Chemical analysis of most soils shows the presence of some soluble salts of ammonia, potash, and soda. Experiments were performed to determine the effect of these salts on the electrolytic corrosion of iron plates per ampere per hour. These experiments showed that iron was carried off the positive plates, but not re-deposited on the negative plates. The iron was deposited in a layer of hydrate or hydroxide of iron near the middle of the experimental cell.

The cells containing nitrates gave off oxygen at the anodes, and showed an acid reaction at the cathodes, which increased with the current.

From the above-mentioned tests the theory was deduced that in an electrolytic cell, with iron electrodes and soluble salts of alkalies in solution in the electrolyte, the salt is electrolised by the current, and the acid radical attacks the anode, forming an iron salt, while the alkali forms with the water a hydroxide at the cathode, liberating hydrogen there; the meeting of these two products by diffusion facilitates the formation of ferrous hydroxide. A comparatively strong current will liberate more acid radical than can combine with the iron. This excess forms an acid combination with the water, and liberates oxygen at the same time. Neither the gas nor the acid can combine with the anode, which is already engaged in forming an iron salt with the acid radical, and therefore the oxygen escapes into the air.

The soil frequently contains carbonates of calcium and magnesium, which causes a reddish layer of iron carbonate to be found on the pipes, and which is frequently mistaken by casual observers for oxide of iron. The results of many experiments and the condition of corroded water pipes, lead to the conclusion that corrosion primarily proceeds by virtue of the acid radicals of the hydrochloric, nitric, sulphuric, and other acids—the carbonates held in solution by virtue of the carbonic acid acting merely to change the ferrous salts to the normal iron carbonates, and the ferric salts to ferric hydroxide. Should the carbonates in solution be electrolised, in addition to the salts of the alkali metals, the carbonic acid radical would not attack the iron—as the corrosive power of the other acids is so much greater—but would again form with the ferrous salts and iron carbonates.

It is surprising how low a voltage produced an appreciable electrolysis in the experimental sand cells employed in making the above tests.

The conclusions which Professor Jackson draws from his numerous and most elaborate experiments are the following:

1. In no case is the action due to the electrolysis of water; where oxygen is liberated at the anode it does not attack iron.

2. Only a mere directive force in the nature of the pressure will cause electrolysis.

3. The corrosion is only dependent upon the current which flows, and is therefore as dependent upon the resistance of the soil as the pressure tending to cause the current.

4. A small quantity of soluble salt will start the action, which will continue as long as a current flows.

5. The corrosion of a pipe depends upon the amount of current flowing from a given area and the nature of the salts in the soil, the order of their activity being:

1. Chlorides. 2. Nitrates. 3. Sulphates.

From the above experiments and conclusions arrived at, it furthermore results that reversing the current in an electric railway at frequent intervals would be of no use, and the only result would be a corrosion of both positive and negative plates. The use of alternating currents would, of course, do away entirely with the troubles arising from electrolysis, but would very greatly interfere with telephones using the earth as a return.

Heavy bare copper supplementary wires have been used on many roads regardless of expense, when a far smaller amount of copper judiciously applied in bonding would have produced a much more efficient return circuit. To know how heavy the bonding and the insulated return feeders should be, a careful study of each road and the conditions under which it will be operated is necessary.

Each feeder must be calculated so as to give the admitted fall of potential with the maximum current which it will have to carry, say 10 per cent. of the station voltage.

The especial factors governing the capacity and number of feeders to be used are: the number and weight of cars in service, their speed and headway, grades, curves, and weight of rails used. The insufficiency of the bonding which has till quite recently been adopted, and the superfluity of employing separate bare copper wires (Fig. 38, page 47), when a good return

circuit is assured by the rails alone, if they are properly bonded, is seen by looking at the following Tables by Mr. McTighe, of Brooklyn, who is connected with the Atlantic Avenue Electric Railway of that city.

TABLE XX.—SECTIONAL AREA OF RAILS AND CORRESPONDING COPPER BONDING FOR DOUBLE TRACK.

Weight of Rails in Pounds per Yard.	Total Sectional Area.	Equivalent in Copper.			Approximate Number, B.W.G.	Resistance per Mile.
		Sectional Area.	Thickness.	Width.		
lb.	sq. in.	sq. in.	in.	in.		ohm
50	20	3.33	1	3.33	20 No. 0000	0.0121
60	24	4.00	1	4.00	24 No. 0000	0.0101
70	28	4.66	1	4.66	28 No. 0000	0.0086
80	32	5.33	1	5.33	32 No. 0000	0.0075
90	36	6.00	1	6.00	36 No. 0000	0.0067
100	40	6.66	1	6 66	40 No. 0000	0.0060

TABLE XXI.—BONDING USUALLY ADOPTED PER MILE OF DOUBLE TRACK.

Weight of Rail.	Bonds Used.	Resistance of Rails.	Resistance of Bonds.	Total Resistance of Return.
lb. per yard		ohm	ohm	ohm
70	No. 000 B. and S. copper bonds, single, 36 in. long. No supplementary wire	0.0086	0.0083	0.0169
70	No. 00 B. and S. copper bonds, single, 12 in long. No supplementary wire	0.0086	0.0027	0.0113
90	No. 0000 Copper bonds, double, 12 in. long. No supplementary wire	0 0067	0.0011	0.0078

The area of the rails in contact with the fishplates is too small and oxidised to be of any service for the return circuit.

Table XXI. gives a too light bonding; the conductivity of the bonds used should approach that of the rails as nearly as possible, especially if the traffic is heavy.

We see from the above, that for the 90 lb. rail, with double track and 12 in. double No. 0000 B. and S. gauge copper bonds, the fall of voltage per mile per ampere passing through the rail, is approximately 0.0078 volt. If the current passing should be such that the fall becomes too great, insulated return figures should be added, connected to the rails at intervals, and brought either overhead or underground, back to the negative "bus" bar at the switchboard in the power-house.

A galvanometer is generally used to measure the fall of potential between the rails and water pipes. Mr. Harold P. Brown, of New York, has, however, substituted a method which would seem more accurate and more easily carried out. A wagon is equipped with a small switchboard and a set of six Weston instruments. Two voltmeters reading up to 750 volts measure the pressure between the trolley wire and rail and between the trolley wire and water pipes. Three other voltmeters serve to measure the pressure between the rail and pipe. One of these reads up to 1.5 volts in thousandths, one up to six volts in 30ths, and one up to 150 volts. Any of these instruments can be placed in circuit or have its terminals reversed by means of a single switch, and the switch is arranged so as to throw a milli-voltmeter with a shunt into parallel on the circuit on rails to pipe, so as to shew the current flowing between these.

The question of stopping electrolysis of pipes and underground metallic conduits resolves itself into two particular problems. Firstly, the maintaining of the pipes negative to the rails at all points, thereby checking corrosion of pipes except at those places where they are insufficiently connected, but at the same time this increases the current flowing through them. The second problem is to maintain the rails at a distance and near the pipes at a nearly constant potential, thereby reducing the current flowing to a minimum. Now supposing the pipes at one place are more negative than the rail, a path for the current must be provided which will be of less resistance than the path through the earth to the rails and generators. To do this a special generator is provided, the positive pole of which is connected to the trolley wire and the negative pole of which is connected as thoroughly as possible with the water pipe. The pressure of this generator is some ten or twelve volts higher than that of the main dynamos, its pressure being maintained such that the pipes are made to be two or three volts negative to the rails at those points where they were previously positive. It is true that by this means there is a tendency to increase the current flow in the pipes, but this can be prevented by carrying out from the higher pressure dynamo another wire to the rails at a more distant point, and by this means the pressure between distant rail and the pipes may be cut down to one or two volts. By introducing proper rheostats into these wires, it is possible to keep the pipes and the rails at nearly all points at approximately the same potential, thus cutting down the flow of current in the pipes to a minimum.

This system is now working at Buffalo. The auxiliary dynamo

represents about one quarter of the total capacity of the station; but the proportion can be reduced or increased when the plan has been put into service. Its positive pole is connected to trolley wire, its negative pole is connected by suitable feeder wires to the points on the pipes which were previously positive to the rails. The pressure of this dynamo is then adjusted that it gives five to twelve volts more than the main generators. As their positive poles are joined, this difference of pressure maintains the pipes negative to the rails by 12 volts, less the previous positive charge and the loss incurred in passing the current through the feeder wire.

The connections between the auxiliary dynamo and the pipes are made by placing back to back some old tram rails and by bolting them together. Good connection is made between the two by breaking joints of the rails and by placing between them plastic material. The use of the old rails for this service utilises scrap which would be practically worthless for any other purpose, and saves the copper wire. This rail return is then laid in a trench of pine boards, filled with petroleum residuum, to insulate the return from the ground. The current carried is only a few volts different from the track rail, so great insulation resistance is not necessary. The return pipe feeders are run out in different directions from the station to the pipe lines.

At the station the return pipe feeders are all carried to a special "bus" bar in the basement, and the track rail return feeders to another special "bus" bar in the basement. None of the negative feeders are carried to the switchboard. This is on an elevated platform in the power-station, and none but positive wires lead to it. The danger, therefore, of short circuiting by loose wires or tools is eliminated. The switchboard has two positive "bus" bars, one for distant feeders at a high potential and one for near feeders at a lower potential. There are thus four "bus" bars altogether, two positive and two negative.

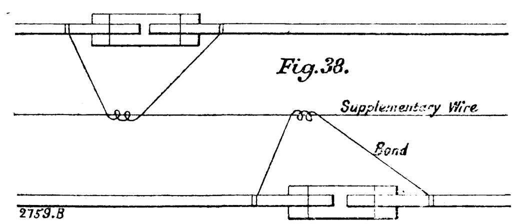
With English conditions, where tramway tracks are usually on six or eight inches of concrete, a very great resistance is offered to the passage of the current from the rails to the pipes. This has been proved in the latest English tramway installations, as for instance at Bristol, where from large water mains only a few feet distant from the rails, and which are heavily connected to the power-station, only $\frac{3}{4}$ of an ampere return, the average output being some 250 amperes. Another proof of the insulating properties of concrete is shown by the fact that on a dead short circuit taking place between the trolley wire and steel poles planted 6 ft. in the ground in a concrete foundation, at a pressure of 500 volts, a current of only 50 amperes

was observed to flow. With good bonding, therefore, and a sound concrete foundation, it does not seem likely that any trouble is to be expected from corrosion in this country.

The following is a description of various forms of rail bonds which have been used, and of those which are now most in favour. There are, besides those described, many other types which have been brought out from time to time, but have never come into general or successful use.

Edison, in experiments with low tension traction (25 volts) and no overhead wires, used the following bonding device :

The rails were connected by the ordinary fishplates and by plates of copper. The rail was cleaned and then amalgamated by rubbing on sodium amalgam. The copper was also amalgamated, the joints were bolted together, a layer of amalgam being interposed between the rail and the copper plate before bolting up. The joints thus made were then covered with marine glue and asphalted. An improvement of this system is known



OLD METHOD OF RETURN CIRCUIT BY MEANS OF BARE COPPER SUPPLEMENTARY WIRE.

as the "plastic" rail bond. It is composed of two portions : a plastic metal compound which makes contact between rail and fish plate, and a case to hold it in position between the bolt holes as near the end of the rail as possible. For different types of rails cases of various shapes are used. For heavy girder rails the case is a flat ring of specially moulded cork, $3\frac{7}{8}$ inches outside and $1\frac{1}{2}$ inches inside diameter and $\frac{5}{8}$ inch thick. It is treated with a viscous insulating compound which will not oxidise or crack. With a hook-shaped scraper or a small emery wheel the scale is removed from the surfaces on rail and fish plate where the cases are to be placed. The centre of each of these surfaces is rubbed with a special alloy, which forms a silver-like deposit, repelling water. One side of the case is then slightly warmed and thus made viscous, and placed upon the prepared surface of the web of the rail. As soon as it sticks, a plug of the plastic metal, surrounded by a steel spring, is put into the hole which slants downwards towards base of rail, so as to retain the free liquid metal in the

compound. A second case and plug are similarly placed on the adjoining rail and the fishplate bolted down. The tightening of the bolts compresses the cork to half its former thickness, and makes its surfaces stick firmly to the steel, the spring forming a distance piece to prevent too much compression. The fishplate nuts are locked in position. It is stated that should they slacken and the plate drop back one-quarter of an inch, the cork will expand or be pulled out to its former thickness by the adhesion of the insulating compound to the steel, and the plastic metal, by gravity and the expansion of the spring, will maintain a perfect electrical contact. For cross-bonding or feeder wire connections a third bond is placed on the rail near end of fishplate, and is clamped upon a tinned strip of sheet copper which projects beyond the plate far enough to be soldered to the wire.

The early rudimentary type of rail bond derived from steam railway signal system practice, has already been described, and is shown in Figs. 39 and 40.

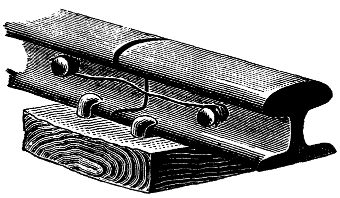
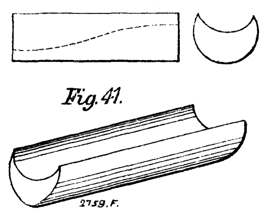


FIG. 39.

FIG. 40.



FIGS. 39 AND 40. EARLY AND INEFFICIENT METHOD OF BONDING. FIG. 41. CHANNEL PIN FOR RAIL BONDING.

The "channel pin" method of bonding, which was next introduced, was once most extensively used, and from a constructive point is very economical. It is now, however, entirely out of date, many better methods of bonding having become known.

It consists in jamming a bare copper wire into a hole drilled in the web of the rail, by means of a coppered steel pin provided with a conical channel. The great defect of this system lay in the fact that the bond could not be riveted or made to completely fill the hole, and a rapid corrosion of the contacts took place. Moreover, the surface of copper in contact with the rail was very small, and the wire, being wedge-driven into the hole in the rail, had a tendency to work loose with the vibration caused by the passage of the cars (see Fig. 41).

A rail bond used to some extent, and which, although by no means as good as later types, was an improvement on the channel pin, is represented

in Figs. 42 and 43. It consists in a tapered, spring steel cap, fitting over the end of the bonding wire and into the web or flange of the rail. The end of the bond wire was passed through the hole in the rail, which was drilled $\frac{1}{32}$ in. smaller than the outside diameter. The cap was then placed over the projecting end of the bonding wire and driven into the rail. A crimp extending the full length of the cap allowed the steel to be compressed firmly over the wire and into the rail. It would, however, seem that the empty space which remained where this process was used caused as rapid corrosion of the contact surfaces to take place as happened where the channel pin bond was employed.

A somewhat similar method of obtaining the same result is attained in the "Acme" rail bond, which consists of an iron sleeve with a tapered end. This sleeve has a channel cut on one side, making the wall of the

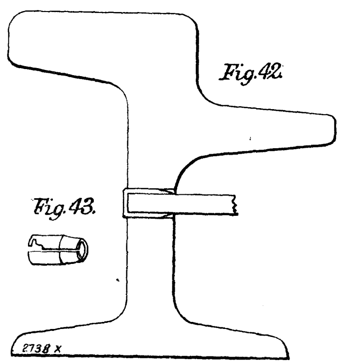
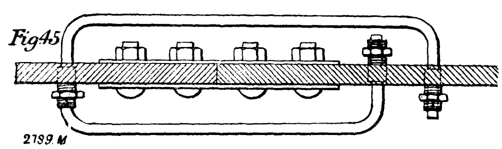



FIG. 44.



FIGS. 42 AND 43. SPRING CAP BOND. FIG. 44. BROOKLYN RAIL BOND.
FIG. 45. SCREW NIPPLE RAIL BOND.

sleeve rather weak at that point. The hole in the rail is drilled about $\frac{1}{32}$ in. smaller than the largest outside diameter of the sleeve, and by driving the sleeve over the wire in the hole of the rail, the sleeve shapes itself to all the inequalities of the hole and the wire, and makes a fairly good joint.

The "Brooklyn" rail bond, as its name implies, has been extensively used in that city. It is formed of a strip of copper, bent so as to provide for expansion and contraction. A drive fit tapered iron rivet at either end holds it to the rails. Besides being liable to break in the middle, the conductivity of the connections with the rails is insufficient, and the use of this bond is not to be recommended (Fig. 44).

A form of bond used to some extent in Philadelphia, consists of a steel screw nipple bored to fit the bond wire, and tapered and slotted at one end

by three slits extending about half its length. The hole in the rail is threaded to receive the nipple, which is then screwed in, the copper bond wire is placed within the slotted end, and a nut screwed up on the nipple until the three segments are brought together so as to clamp the bond. The labour required to instal these bonds is more than with most other forms, and the contact surface of the copper with the iron is not sufficiently perfect to make the bond desirable (see Fig. 45).

The solid riveted copper bond consists of a piece of No. 0 to No. 0000 wire, at each extremity of which a head is formed, which is riveted into the web of the rail. The rivet portion of the bond is larger in diameter than

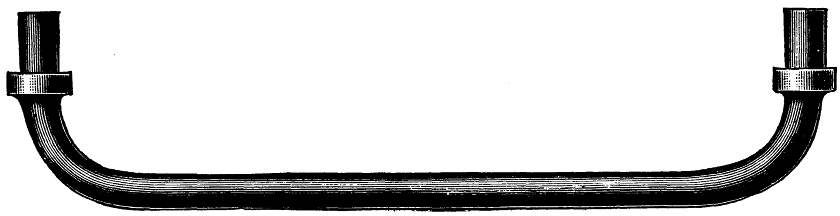


FIG. 46. SOLID COPPER RIVETED BOND.

the wire itself. In bonding, the rivet head and riveted end are pressed tightly against the side of the web, thus forming a very fairly perfect joint (see Fig. 46).

This bond is generally manufactured in two lengths, viz., $8\frac{1}{2}$ in. and 30 in. The $8\frac{1}{2}$ in. bonds are used for riveting to the bottom flange of the rail, the 30 in. one being riveted into the web of the rail at each side of the fishplates.

TABLE XXII.—STANDARD RIVETED TYPES OF BOND.

Size of Wire, B. and S. Gauge.	Diameter of Hole in Rail into which end of Bond Fits.	Dimeter of Bond Wire used.
	in.	in.
0000	$\frac{1}{2}$	0.460
000	$\frac{1}{2}$	0.410
00	$\frac{7}{16}$	0.365
0	$\frac{3}{8}$	0.325

The "Vail" bond is in some respects a good bond, although it relies to some extent on external contact surface. It consists of two heavy sockets of copper, one riveted to each rail, and connected by two or more stranded copper cables brazed into the brass or copper sockets. The sockets have two or more projecting studs which are riveted into the web of the rail.

These furnish a fair electrical connection with the rail, and the shoulders of the sockets can also be slightly relied upon at their contacts, provided the work is well done and the surfaces in contact were bright and dry at the time of their connection. Solid bonds are, however, preferable to flexible ones, as they are less liable to damage by electrolysis.

The "West End" bond consists in a solid or stranded copper wire having iron tapers brazed on to it at the points where the bond is driven through the web of the rails. After the tapers have been forced into their proper position, the free ends of the bond are brought together and fastened by means of a soldering sleeve (see Fig. 47).

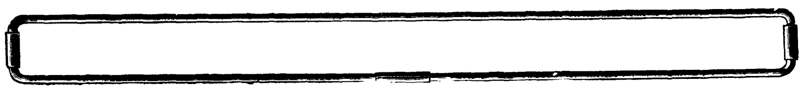
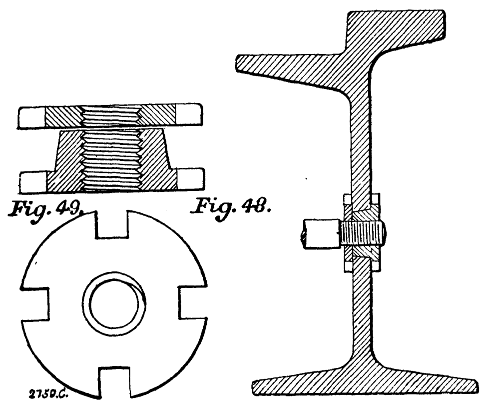


FIG. 47. "WEST END" BOND.



"JOHNSTON" RAIL BOND.

In the Johnston rail bond—one of the latest types—all rivets are avoided, and the bond is applied to the rail by means of two nuts, shown in Fig. 49, which are applied to the end of the bond, as shown in Fig. 48. The web of the rail is perforated by a taper hole, and after the insertion of the bond the nuts are screwed up tight and force the tapered nut into the hole, as shown in Fig. 48. The surfaces are first made smooth and bright by a special tool, after the rail is in position. The holes for the nuts are also tapered and made bright by the use of another tool—the bright smooth surfaces of the steel and brass nuts and their flanges making a firm, electrical, and mechanical water-tight contact, with all the possible solidity to be obtained by the use of bolts and nuts. This fastening is reinforced by slightly upsetting the protruding end of the copper rod on the end nut after

the whole is in place. After the bonds are installed the joints may be soldered, but should be thoroughly coated with a suitable preservative compound. The diameter of the hole in the web, together with the faces of the nuts, gives an area of contact much exceeding the cross-section of the bond itself. The size of the wire used in connection with the Johnston bond can, of course, be varied at will, as is the case with all bonds, those nearest the power-house being made larger to allow for the increased current at that point. This can be done, however, without altering the bond nut, all that is necessary being to tap it to the size of wire desired.

Fig. 50. Drilling Rails and Bonding with "Chicago" Bonds at Bristol, England.

The present standard size is No. 0000 B. and S. copper rod (say, $\frac{15}{32}$ in. in diameter), 30 in. long (measuring from the centre of the holes in the rails).

The "Chicago" rail bond has now practically become the accepted American and European standard. It has been employed at Bristol, Dublin and Coventry, as well as by many of the best continental and colonial lines. The bond consists of a copper rod or flexible cable having tubular or thimble-shaped terminals which are bent at right angles to the bond, the whole being composed of one solid piece of rolled copper. The tubular or thimble-shaped terminals are inserted into holes through the web of the rail, and the slitted end of the

terminal is spread or clinched over on the rail with a hammer and punch; this holds it from drawing back out of the hole. Rust should be cleaned out of holes with a straight rose reamer not exceeding the size of the terminals more than $\frac{1}{64}$ in., or they should be cleaned with a round file a size smaller than the holes. If from any cause, as from an oversight or negligence, or from reaming the rust out of holes, they should be made too large for the terminals, making a loose connection, pins $\frac{1}{64}$ in. larger than the original pins sent out with the bonds should be used, and in applying these larger pins a punch should be used to open out the terminals to start the pins straight. The drift pin is larger in diameter than the opening in the tubular or thimble-shaped terminal by about $\frac{1}{16}$ in. This pin is driven into the hole in the terminal, thus permanently expanding and wedging the terminal into solid contact with the surface of the hole through the web of the rail by stretching or swaging the metal of the bond against the sides of the hole in the rail. This makes, as nearly as may be, an absolutely perfect and solid contact between the two metallic surfaces in connection, excludes all air and moisture, and renders corrosion or electrolytic action in the connection very nearly impossible. The usual length of bond is 30 in. Instead of using solid wire between the terminals, stranded cables can be employed, but present no substantial advantage over the solid wire. Table XXIII. gives the proportionate dimensions of standard sizes of this bond.

TABLE XXIII.—SHOWING STANDARD DIMENSIONS OF CHICAGO RAIL BOND.

Size of Wire B. and S. Gauge.	Diameter of Hole in Rail into which Terminal of Bond Fits.	Diameter of Hole in Terminal.	Sectional Area of Rail Bond.	Diameter of Pin.
	in.	in.	sq. in.	in.
0000	$\frac{7}{8}$	$\frac{7}{16}$	0.166	$\frac{1}{2}$
000	$\frac{3}{4}$	$\frac{3}{8}$	0.132	$\frac{7}{16}$
00	$\frac{5}{8}$	$\frac{6}{16}$	0.104	$\frac{3}{8}$
0	$\frac{1}{2}$	$\frac{1}{4}$	0.083	$\frac{5}{16}$

The depth of the hole in the terminal (not including point) is 1 in. in all sizes of the bond.

The advantage of this bond is the large contact surface it has inside the web of the rail, and the extremely good contact assured between the copper and iron. The size of conductor used depends upon the weight of the rails and the current carried (see Figs. 51 to 53).

A very good practice to diminish the electrolysis and corrosion of rail bonds, would seem to consist in heavily coating them with preservative compounds. Insulating the rails as much as possible from the ground by laying them on good rock ballast, and heavily coating them with tar, asphaltum, or other preservative compounds, is recommended by practical street-railway constructors. The most thoroughly reliable preservative and insulator combined is that known under the trade name of "P & B" A faulty rail bond will show itself in winter by heating and melting the snow

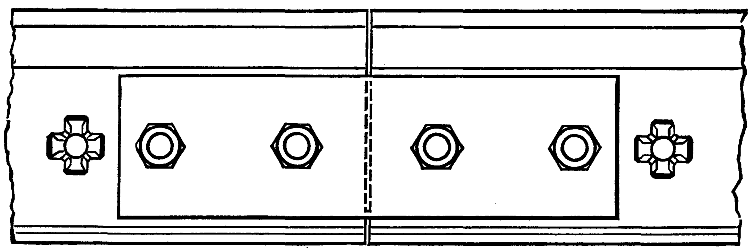


FIG. 51.

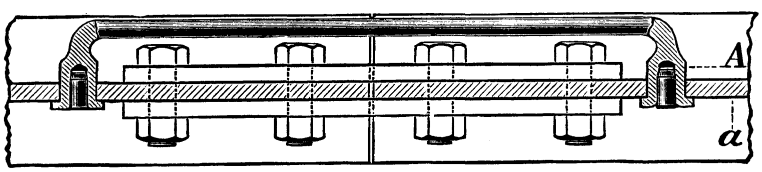


FIG. 52.

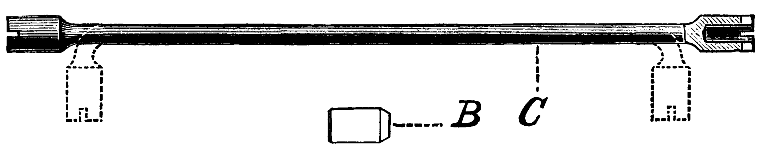


FIG. 53.

"CHICAGO" RAIL BOND AND METHOD OF APPLICATION.

which may be present on the ground around it. If the earth is fairly dry, and presents some resistance, faulty rail bonds will also show themselves by causing slight shocks to people or animals touching the metals, due to a difference of potential existing between the consecutive rails. Besides causing loss of power and electrolysis of gas and water pipes, a defective return circuit causes burnt armatures, hot motors, and frequent repairs. From the foregoing we may conclude :

1. The rails ought to be bonded in such a way that the current capacity of the bonds is, as nearly as possible, equal to that of the rails.

2. Supplementary bare copper wires laid in the earth between the rails are useless (see Fig. 38). If the rails are not heavy enough to carry the current required, insulated return feeders connected to them at intervals should be adopted.

3. The rails should be heavily cross-bonded at least every 90 ft. or so, in order to equalise the current flowing through each line of rails as much as possible.

4. The greatest care should be taken to have the surface of the rail in contact with the bonds perfectly dry and bright at the moment of bonding. Only the surface within the holes in the web should be counted upon as absolutely reliable for the path of the current, and no portion of the external surface of the web of the rail should be considered in calculating the contact surface required.

5. The resistance of the return circuit should be so low as to need no help from the earth.

It is of the greatest importance that the surface of the copper bond which is in contact with the rail should be as large as possible, from six to ten times the sectional area of copper bond.

The density of the current in the bond should also be low.

CHAPTER IV.

THE RETURN CIRCUIT—*continued.*

WE now come to the electrical welding process, which, if successful, will do away with all bonding and use of copper wire, except where return feeders are necessary in connection with the return circuit. It practically means the use of continuous rails without joints of any kind. It has already been stated that it is now a nearly universal practice in America to butt the rails, without leaving any room for expansion at the joints, and that in paved streets nearly perfect joints have been the result. The Johnson Company, of Johnstown, Pennsylvania, have gone still further, and after an exhaustive series of experiments, have undertaken to weld the rails instead of connecting them by fishplates, Their system was first tried at Cambridge, Massachusetts, on a branch of the West End Street Railway Company, of Boston. The method of operating was as follows: The fishplates were removed, the ends of the rails cleaned by an emery wheel on a flexible shaft, a thin piece of steel was forced between the rail ends and a pair of fishplates of the form shown in Fig. 54.

A welding car, specially constructed and self-propelling, was then brought up the track and the weld made, the current being taken from the trolley wire and transformed into an alternating current at low pressure. In making these welds the fishplates were grasped by specially arranged jaws, and welded separately to each rail. The ends of the rail were not welded together, but the fishplates, which were 4 in. by 7 in. by 1 in. and of form shown, were joined to each rail, thus necessitating two operations for each joint. The first road which was operated upon had a very old and poorly constructed permanent way, and it was soon found that most of the welded joints broke off, not at the weld, but just below or above it. This led the Johnson Company to devise a new plan which has since been employed apparently with great success.

The next road on which track welding was tried was the Baden and St. Louis Railway of St. Louis, Missouri. Welding was begun on this line in February, 1894. The road has many curves, and the rails were first bent

and laid, and then welded in place. It was found necessary to lay the track and tamp and surface the line completely before commencing to weld the joints, as otherwise the weight of the welding car would have depressed the rails in the middle and raised them at the ends, thus causing the welded joints to be high. The metals were spiked to wooden sleepers, 3 ft. between centres, laid on 6 in. of macadam, well rolled, and the track was then tamped to grade and filled in to the tops of the sleepers or ties. The rails were then ready for the welding of the joints. The welding car was in this case equipped with two "W. P. 50" electric motors, and all the speed regulating and starting devices of an ordinary electric street car. The current coming from the trolley wire passed through an automatic circuit-

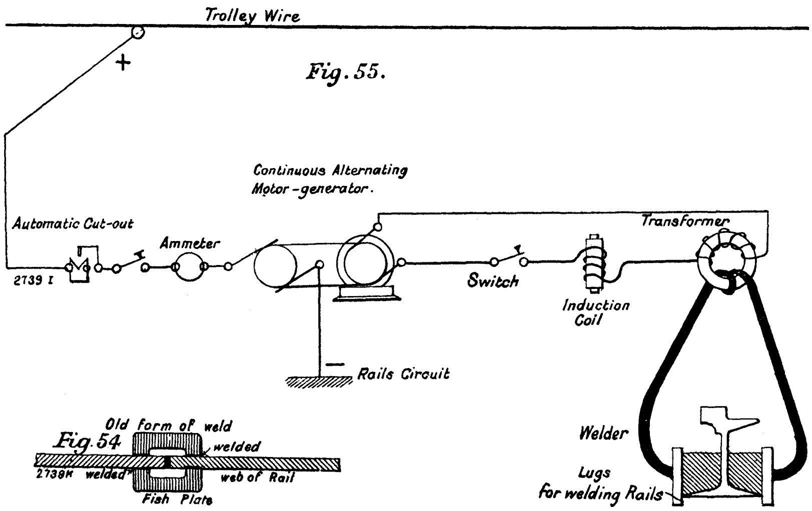


FIG. 54. FIRST FORM OF WELDED RAIL JOINT. FIG. 55. DIAGRAM OF RAIL WELDING CIRCUIT.

breaker, switch, ammeter, and starting rheostat, to a transformer or motor generator which transformed the 500-volt continuous current into an alternating one. The periodicity of the alternating current used was from 73 to 74 per second. This alternating current then passed through a break switch and regulating induction coil with movable iron core to a transformer, where it was transformed into a current at a pressure of from three to four volts, which traversed the welding machine. For convenience in working, this machine was hung from a crane. The secondary winding of the transformer consisted of a single turn of very heavy copper strips, leading to the copper contacts between which the weld was made (see Fig. 55). The distance between these contacts was regulated by a screw gear, by means of which a very large pressure could instantaneously be brought to bear upon the weld.

I

The welding car also contained a motor for operating the crane, and another which drove a pump forcing cold water through the hollow arms of the welding machine. The weight of this welding car was about 30 tons. It was preceded by an auxiliary car carrying two electric motors driving emery wheels on flexible shafts, which were used for polishing the rails where the joint was to be made, previous to welding. The mode of operation was as follows:

The ends of the rails were butted together by driving a wedge in the joint ahead of the one to be welded. The welding car was then run over the joint, the welding being done from the rear, so that it was not necessary to run over a hot joint. The webs of the rails were polished by the emery wheels for 2 in. on each side of the joint. The joint was then clamped in a gun-metal casting holding the rails in the proper position for welding. The two steel lugs, 1 and 2, shown in Fig. 56, were placed each side of the joint,

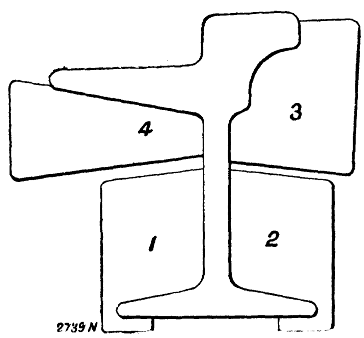


FIG. 56. POSITION OF STEEL LUGS USED IN WELDING RAIL JOINTS.

resting on and partly surrounding the foot of the rail, and the contact clamps screwed down upon them. The electrical circuit of the secondary coil of the transformer was thus completed, and the current was gradually turned on. When the welding heat was reached, the jaws of the welder were brought tightly together, thus forcing the molten steel into the joint between the ends of the rail. Then the top lugs, 3 and 4 in Fig. 56, were inserted and the same process gone through. Previous to turning on the current, pieces of carbon were placed on the top of the rail to prevent the joint softening. After the lugs were welded, the tread and flanges were smoothed by hammering, the hammer being contained in the welding apparatus. The welds on the St. Louis road are so well executed that it was well-nigh impossible in most cases to distinguish where joints had been welded. By this process enough molten steel enters the joint between the rails to make a butt weld, besides which additional security is afforded by

the lugs welded to the web of the rail. The greater part of the time is taken up in preparing the joints, moving the machine, and setting up the welder. The average time occupied in making a joint is from 12 to 15 minutes, and it was said that the cost ran from 12s. to 15s. per weld. The current is taken from the trolley line at an average pressure of 500 volts, and averages 250 amperes for from two to three minutes. The pressure of the secondary welding current used is from three to four volts, and taking into consideration the losses in the various transformations, the welding current would probably amount to from 40,000 to 50,000 amperes. No buckling had been observed in July, 1894, when the writer visited the line. The track was filled up as soon as possible after welding, but on several occasions 300 ft. to 500 ft. of welded track were left open for several days without any bad results ensuing. So far $3\frac{1}{2}$ miles of double track have been treated in this way at St. Louis, and the manager, Mr. R. McCulloch, expressed himself as extremely satisfied with the results attained. The electric railway which has so far adopted electric welding on the most extensive scale is the Nassau Electric Railway Company, of Brooklyn, New York, where over 100 miles of track will soon be continuous.

The welder used here is an improvement on the one which was employed at St. Louis (see Figs. 57 and 58). The equipment is contained in two cars instead of one. The first car contains the motor generator. The alternating current coming out of the motor generator is conducted at a 300-volt pressure to the step-down transformer and welder in the second car which is nearest the joint. Instead of using a screw jack to tighten up the gun-metal welding clamp, hydraulic power is employed. The width of the lugs used in welding has also been increased, and the rails are polished $3\frac{1}{2}$ in. on either side of the joint by means of an emery wheel carried on the first car. Against the head of the rail a non-conductor of heat is placed so as not to cause any loss of temper in the rail. When the rails are laid, two out of three joints are butted, a space of $\frac{1}{16}$ in. being left every third rail. When the non-butted joint comes to be welded, a thin section of rail is driven in between the two ends, which renders the rail continuous. The rails are also cross-connected together every 600 ft., so as to secure a good return circuit for the current, by welding a flat steel bar $1\frac{1}{2}$ in. by $2\frac{1}{2}$ in. in dimension from rail to rail. Where the line is double track, the interior rails of each track are also welded together every 600 ft. in a similar manner.

Whether electric welding will eventually take the place of all bonding is still an undecided question. It has not yet stood the test of practical

use under all conditions of weather and traffic, and on a large scale, for a sufficiently long period to pronounce an opinion. The equipment in Brooklyn will be watched by all electrical street railway operators with the greatest interest, and the result will go a long way towards deciding conclusively in favour of or against welding. At all events the pioneer company in this line of work seems to have great faith in its success, and it is said that they have already invested over £120,000 in experiments and practical application.

Another process of attaining the same results as with electrically

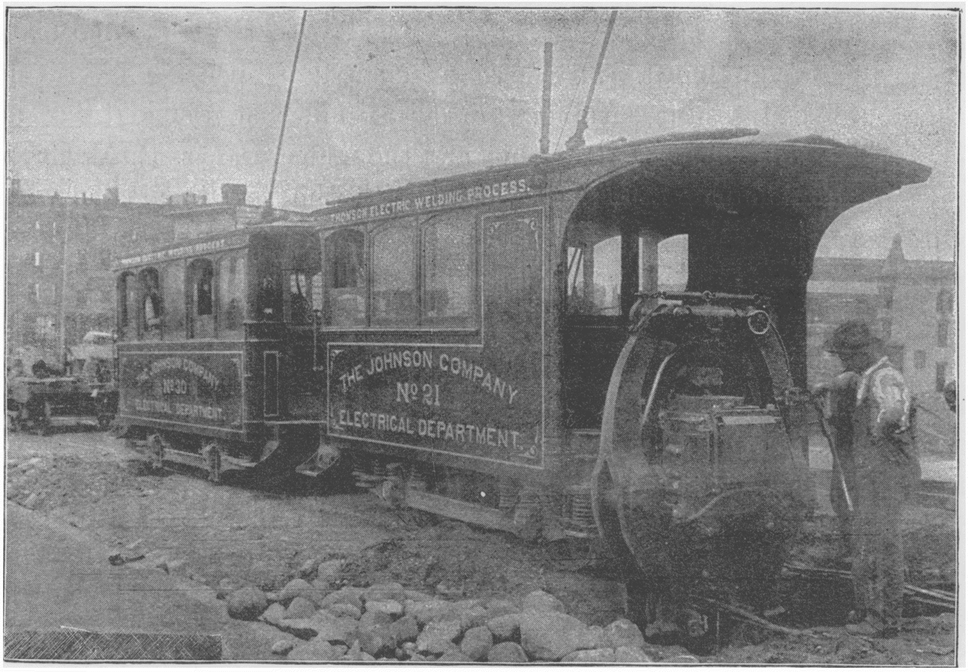


Fig. 57. Welding Train.

welded joints has just been experimented with by Mr. McCulloch, of St. Louis. It consists in welding the joints of the rails together by casting a cast-iron sleeve round the sides and bottom of the joints. It has been carried out for a length of three miles of track at St. Louis by the Falk Manufacturing Company of Milwaukee. This process was first shown in October of last year at the Atlantic Street Railway Convention. The outfit is composed of a small smelting cupola on wheels, weighing about three tons and drawn by two horses. A light steam blower is attached to the cupola, and oil is burnt under the blower.

The cupola is 2 ft. in diameter, brick lined, and the blast is furnished

by a Sturtevant blower, driven at 1,800 revolutions per minute, by a 5-horse-power motor, which receives its current from the trolley. The iron used is one-half best soft grey pig and one-half selected scrap. The scrap consists of old gear wheels, manhole covers and frames, an abundance of which are found in the scrap heap of the railway. The furnace works very rapidly, and in twenty minutes after the blast is turned on the iron is ready to pour. It may then be tapped as long as the charging is continued at the top. As the machine has been operated on the Citizens railway, about 1,200 ft. of track has been prepared and all the joints moulded in one heat. As many as 72 joints have been poured at one melting.

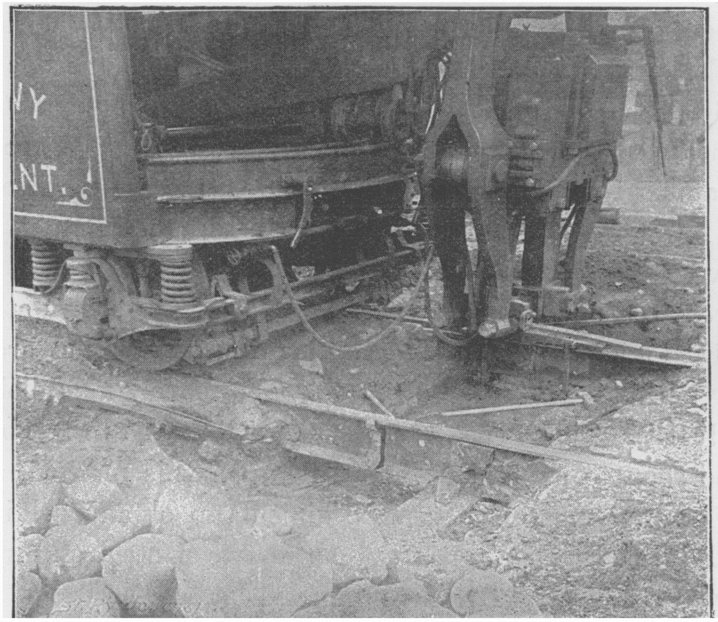


FIG. 58. RAIL WELDER.

The preparation of the joint for casting is as follows :—

The fishplates are first taken off, and the rail ends for about 8 in. back polished with garnet paper. Openings between ends are closed by driving in a thin section of rail. The moulds, consisting of two castings made to fit the rail, are then placed about the joint and clamped in position. A heavy clamp is placed on top of the rail, and screwed up as tightly as possible to hold the joint immovable while being poured. This clamp is left on the rail until the casting has cooled. Preparatory to the pouring, the moulds are lined with a mixture of linseed oil and plumbago, and are heated to drive out any moisture in them or on the rail. The pouring operation is very simple.

The melted iron is run from the cupola into a ladle, and then slowly poured into the mould. This final operation is very quickly performed, as it usually takes about three hours to pour forty joints. The casting weighs 1 cwt. 37 lb., and extends back on the rail 7 in., taking in two of the bolt-holes in the ends of the rails. In this way four bolts are cast through the rail. A sort of welding action seems to take place between the iron and the steel rail, as on examination of a joint sawed in two it is difficult to tell the exact junction. The moulds are fixed to the rails by screw clamps, and hold the joint in place till the mould is cool and can be removed. The space left at the top between the mould and the rail is made tight by means of moulding sand. An iron plate is laid over the top of the rail at the joint, so as to prevent the cast metal coming up and flowing out between the ends of the rails. A gang of from six to eight men and one cupola will make from 60 to 140 joints per day of ten hours. As already stated, the moulds are heated before using, and the ends of the rails are allowed to heat by the application of the red-hot moulds before the cast-iron is poured into them. After the metal has been cast, about ten minutes are allowed before removing the moulds.

To prevent too severe contraction and expansion, every other joint is cast and allowed to cool entirely before the remaining ones are proceeded with. The joints made weigh 120 lb., and cover four bolt-holes, or approximately 16 in. The cost of such a joint is stated to be about 12s.

It is too soon to express any opinion upon this method, although it would seem as if it must be far more difficult to obtain welding between cast-iron and steel by this process, than between steel and steel at the higher temperature attainable by means of electric welding. The great advantage, of course, would be the cheapness of the outfit as compared with that of an electric welding plant.

In case of defective joints by this process, it is found that the rail ends simply pull apart, the lugs sticking to that rail which held them tightest. In a few instances small pieces of rail pulled off with the lugs, but it is stated that in no case have the rails themselves broken or a joint been known to break which looked as if it had ever been really welded. The result of this experiment is far from being discouraging, and the officers of the railroad company are satisfied that with the additional knowledge now possessed, and with the improvements which have been made in the machine, it is possible to construct a track by this method with little trouble from breakage.

It seems difficult to those accustomed to steam railroad tracks to reconcile themselves to the use of a continuous rail. They call to mind experiences with rails creeping and getting out of place on account of temperature variations. It must be remembered, however, that street-railway tracks differ in one very important particular from those of the steam railways, in that they have a road-bed firmly packed about the rail. The perimeter of a 7 in. rail is 29 in., of which only $6\frac{1}{2}$ or 22.4 per cent. is exposed to the air, while the remaining 67.6 per cent. is covered up and firmly gripped by the road-bed. No one can understand how firm this grip is until they have seen a rail which has lain in a macadam street several years taken up, the whole buried surface of the rail being covered with a hard cement composed of stones and mud. There is a tendency on the part of the rail to change its length with temperature variations, but the road-bed holds it in place.

The strain on rails due to the variations of temperature may be estimated, according to Mr. McCulloch, as follows. Taking a co-efficient of expansion for steel of 0.0000065 and multiplying this by 75 (a liberal figure for the maximum deviation in degrees Fahrenheit from the welding temperature), 0.000487 is obtained, which is that part of its length which a rail would expand due to a rise of 75 deg., or contract due to a fall of 75 deg. in temperature. A steel bar will expand 0.00003 of its length, due to a load of 1,000 lb. per square inch. Dividing the estimated expansion by this figure, the strain amounts to 16,200 lb. per square inch. As the rail is $8\frac{1}{2}$ in. in cross section, equivalent to a weight of 85 lb. per yard, the total pull due to a fall of 75 deg. in temperature is 137,700 lb.

As 40,000 lb. per square inch is a safe value for the elastic limit of steel, it will be seen that in the American climate the elastic limit will never be reached, and this means that these expansions and contractions may go on indefinitely, and as long as the joints remain unbroken no harm will be done to the rail.

Assuming 80,000 lb. per square inch as the ultimate strength of steel, we see that, so far as the strength of the rails themselves is concerned, we have a factor of safety of five.

Taking the figures for the contraction of the rail due to a fall of 75 deg. in temperature, each rail of the St. Louis track should have contracted 8 ~~ft.~~ ~~6~~in. As a matter of fact, when the joints broke, the openings in none of these exceeded 2 in., and the combined openings of one rail for the length of the road did not exceed 6 in. This shows that the pull

which broke the joint was not transmitted, but was the result of a local strain, not extending far on either side of the joint.

The strength of the cast-iron joint is considered equal to the strength of the rail. The area of its cross section at the joint is 61.6 sq. in.

The two methods just described are the only processes of actually welding rails yet put into operation. The electric welding is scientifically a beautiful process, and if skilfully done the joint should theoretically be stronger than the rail itself. The process has the disadvantage of requiring considerable care and intelligence to ensure its being effective. It is impossible to tell simply by looking at a joint whether or not is really welded. On the ordinary railway circuits, where the voltage fluctuates continually, it is difficult to operate the processes successfully. This can be remedied by using storage batteries, which take current from the line when the welding machine is idle, but which are thrown into parallel with the line and assist in maintaining the voltage while the welding is in progress. The welding machine and accessories are exceedingly heavy and difficult to move from place to place where track is not already laid. The great expense of an outfit is also prohibitive.

The cost of these methods, it is claimed, do not greatly exceed the usual fishplate method, but even if it were greater the advantages gained by the abolition of joints would be of great value.

However, we must await future developments before a reliable opinion can be pronounced.

CHAPTER V.

ELEVATED CONDUCTOR CONSTRUCTION.

AT the present writing, but one system of electrical traction has received practical acceptance in America. That system employs elevated conductors suspended above each track for the whole length of the line. Electrical communication between the aerial wires and the car motor is maintained by means of an under-running grooved trolley wheel mounted on a steel pole, and held at a constant pressure against the wire by springs in the base upon which the pole is supported, the base itself being placed centrally on the car-roof.

Accumulators have made no perceptible progress so far as traction is concerned. Their cost has heretofore been prohibitive, and their efficiency extremely low.

One or two small experimental installations are in operation by means of conductors contained in a sub-surface conduit, but they are still in a wholly tentative position.

Between 1884 and 1889 the conduit system was most elaborately worked out and carefully tested in Cleveland, Allegheny City, and Boston, under conditions of actual electric railway service in city streets. One of the original pioneer organisations, the Bentley-Knight Electric Railway Company, of New York City (among whose engineers were a number of those whose names have always been prominent in electrical traction), devoted its energies for some four years to the promotion of the conduit system; and it is doubtful whether any substantial improvement has been made therein since that company gave up the attempt, and joined hands with the Thomson-Houston and Van Depoele companies in the development of the elevated conductor system.

The outlay required to instal a sub-surface system of electrical conductors appears to be quite as great as would be needed for a cable plant. Where the traffic is sufficiently heavy to induce so large a capital investment, it is the general impression that in most cases the cable system would be regarded as preferable by practical railway operators.

With but one notable exception, that of the Cincinnati electric railways (hereafter described), the use of a single, bare copper, continuous, aerial conductor is universal in the United States, the circuit being completed by the use of the rails as conductors, in the manner described previously.

Fig. 59 is a diagrammatic representation of the single conductor system. The current, coming usually from the positive brush of the generator G, passes out to the trolley wire C strung over the middle of the track, and along it until it reaches the trolley wheel T, carried on the top of one of the motor cars; here it divides, a portion going down through the, trolley wheel and pole to the motor M. After passing through the motors, the current reaches the rails J through the wheels, and passing along them is led by the return wire W back to the negative brush of the generator.

The main portion of the current which divided at T, passes on to feed

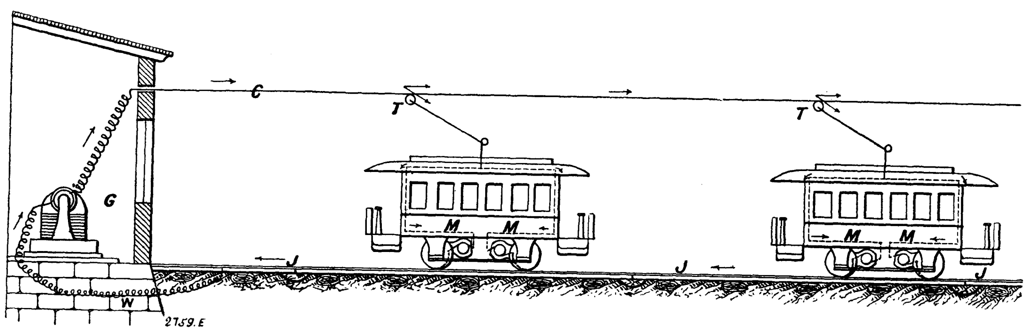


Fig. 59. Diagram of Electric Railway Circuit.

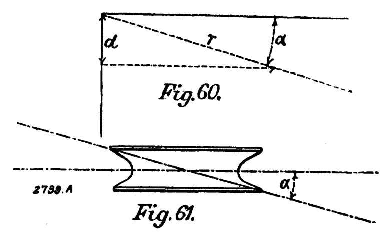
other cars upon the line in the same manner, each car taking from the overhead conductor the current it requires to actuate its motor and no more.

Upon lines where roof seats are not employed, and they are seldom used in America, this bare overhead wire is suspended over the centre of the track at a height of $18\frac{1}{2}$ ft. above the top of the rails, and it must necessarily be insulated from the earth.

The trolley wire which is practically universally used on American street railways is of No. 0 (Brown and Sharpe gauge) hard drawn bare copper, a conductivity of 98 per cent. of pure copper being guaranteed by the best makers. The diameter of this wire is 0.3249 in., and its breaking strain 4,973 lb. On high speed railroads, where heavy Pullman cars are run, a No. 000 B. and S. wire is used, which is rolled in the shape of the figure 8 or a trefoil. This has the advantage of allowing a smooth path to the trolley wheel, as the clips can be attached mechanically to the upper section of the "8" or trefoil, leaving the lower portion always clear.

Many Continental lines have employed lighter trolley wire—in some instances as small as 6 millimetres—and some use larger. It may be taken, however, that No. 0 is the size that gives the best all-round results. Phosphor and silicon bronze are of doubtful utility as substitutes for hard-drawn copper, the advantage of increased strength being more than balanced by the reduction in conductivity. The manufacturers of trolley wire should guarantee perfect joints, and should deliver it wound on special reels in mile or half-mile lengths. Good running and a low rate of depreciation depend largely upon the exactitude with which the trolley wire follows the line of the metals, and pains taken to insure a smooth and even path for the trolley wheel are always well repaid.

Curves are, naturally, the most difficult part of a line to construct, so as to keep the trolley wire as near the centre as possible without unnecessary multiplication of overhead span, strain, and guard wires.



ANGLE OF TROLLEY-WIRE AND WHEEL.

In Figs. 60 and 61, if T represents the projection of the trolley pole on a plane parallel to the track, and a the greatest angle which the trolley wire can make with the direction of the projected trolley pole, we see that d, the greatest distance of the centre of the track from the trolley wire, cannot exceed

$$d = \sqrt{T^2 - (T \cos a)^2}$$

as given by the above formula. As T is generally about 10 ft. (the trolley measuring usually about 12 ft.), and a is approximately 20 deg., we find that this gives for d the approximate length of 3 ft. 6 in., that is to say, the distance of the trolley wire to the centre of the track (if the trolley pole is, as in America, on the centre of the car) must not exceed 3 ft. 6 in., or else the trolley wheel will leave the wire. This distance is in practice never attained, from 2 ft. to $2\frac{1}{2}$ ft. being the maximum ever allowed.

The principal European exception to this method of construction is that adopted in the electrical equipment of the South Staffordshire and Bristol tramways. Local conditions rendering it impossible for the trolley wire to be sustained in the usual manner, an ingenious special arrangement of contact arm has been employed, which allows the trolley wire to deviate from the normal position to an extent equal to the horizontal projection of the trolley pole.

Messrs. Mather and Platt, Limited, and Messrs. Siemens and Halske have also made somewhat extensive use of a frictional collector in the shape of a bar or roller of metal, supported above the car and equal to it in width. This method of making contact does not require the trolley wire to so closely follow a given line.

It is, however, undoubted that the general consensus of opinion is very strongly in favour of the system in vogue in the United States, and that it should be followed in all cases where adverse local conditions are not met with.

To maintain the overhead wire in position, exceedingly neat and ingenious insulating and supporting devices are used in America. In fact, the wide extension of electric traction is largely due to the enterprise of independent manufacturers, who, seeing a great and growing need, undertook the elaboration of a system of electric tramway supplies to meet the demand, and relieved the electrical companies of constant consideration of the details necessary for safe and economical transmission of current from power-house to car motor. The taut and workmanlike overhead line of to-day, in erecting which the lineman has had at hand a compact and appropriate device for every insulating or supporting point, differs widely from the unsightly webs which were the rule in earlier years.

In the early days of electric traction, no greater annoyances fell to the lot of the much-tried constructor than those which seemed inseparably connected with the suspension and and effective insulation of the conducting wire. No material was obtainable possessing the happy combination of strength, durability, and high insulation with inconspicuousness; interchangeability of parts was unknown; and unsightly rough-and-ready expedients were used wherever difficulties in erection were encountered. From 1884 to 1889 no insulator better than paraffined wood or porcelain could be obtained. The earliest elevated conductor lines were dependent for their insulation upon the wooden poles by which they were supported, and in wet weather the resultant leakage was a very serious factor.

With the introduction of iron poles and the development of motors and power plant, something better and more permanent became a necessity.

The illustrations in this and following chapters fairly represent the best known and most widely used apparatus.

We do not propose to consider the question as to whether any one insulating material has greater merit than another, but it cannot be too emphatically pointed out that in the selection of the class of appliances to

be used, the nature and needs of the individual road must be borne carefully in mind.

For a suburban line and light traffic, where economy in installation is a first requirement, the type of insulator shown in Figs. 62, 63, 64 and 65 serves the purpose well. The series in this type includes a straight line insulator, single and double pull-off for curves, and a bracket arm hanger. The construction is shown in section.

In this type, the homogeneous mass of insulating material, while still in a plastic state, is forced under heavy pressure into a casting provided with internal flanges to hold it securely in place, and external points to which the span or strain wires may be attached. The threaded thimble is moulded into the insulating material at the same time. The threads are

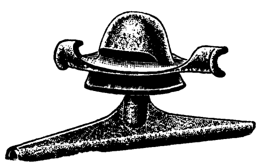


Fig. 62.

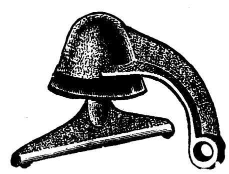


Fig. 63.

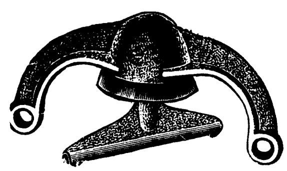


Fig. 64.

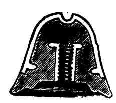


Fig. 65.

Figs. 62 to 64. "Ætna" Insulators for Suburban or Country Lines.

made to take $\frac{7}{16}$ in. or $\frac{5}{8}$ in. screw studs, according to the strain they are to sustain. The metallic parts, which partially protect the insulating substance, are of either bronze or malleable iron. In this type the strain and weight of the trolley wire is taken by the insulating material itself.

This is the type of insulated suspension which has been employed by the South Staffordshire, Douglas and Laxey, and Guernsey lines, as well as by many Continental and Colonial roads.

To supply the needs of tramways where constant and heavy traffic is to be expected, and where security to the service is of far more importance than small economies in first cost, the "West End" type of insulating material has been evolved. This series is more elaborate than the former, comprising a straight line insulator, single and double pull-off, bracket-arm hanger, and bridge, spring bridge, and car-house insulators (Figs. 66 to 72).

These are far more substantial than those first described. The

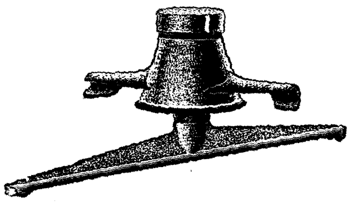


Fig. 66. "West End" Straight Line Insulator.

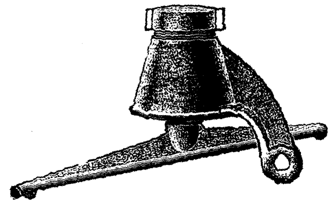


Fig. 67. "West End" Single Pull-Off.

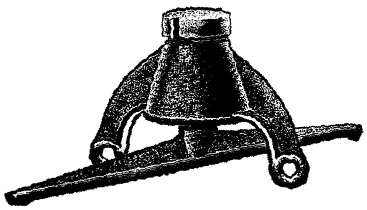


Fig. 68. "West End" Double Pull-Off.

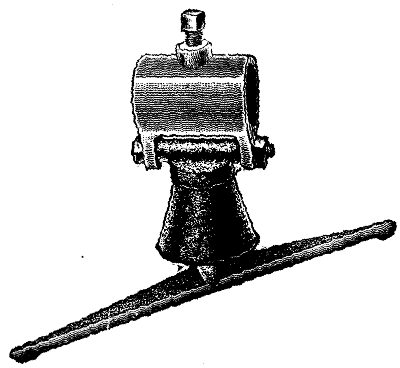


Fig. 69. "West End" Bracket Arm Insulator.

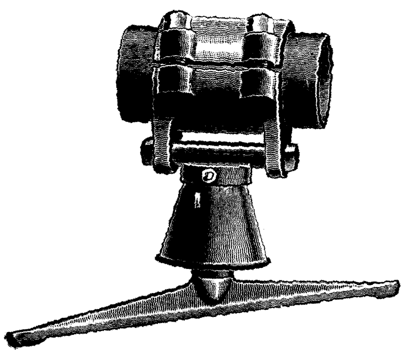


Fig. 70. "West End" Bracket Arm Insulator, Double Insulation.

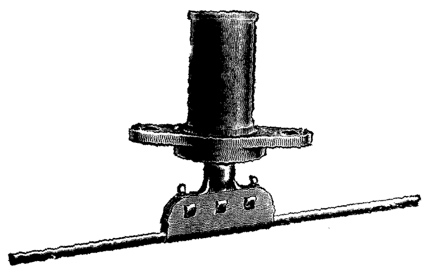


Fig. 71. "West End" Spring Bridge Insulator, with "Anderson" Mechanical Ear.

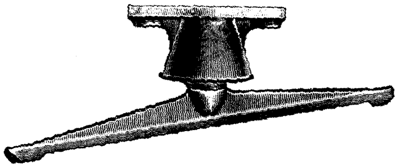


Fig. 72. "West End" Bridge or Car-House Insulator.

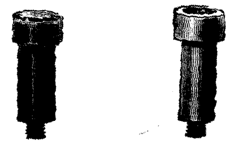


Fig. 73. "West End" Insulated Bolt and Feeder Plug.

essential difference in construction is that the insulation is wholly protected from injury from exposure or chance blows, by a metallic skirt, and that no part of the strain comes upon the insulating material itself, the load and strain being wholly taken under all circumstances by the heavy metallic parts of bronze or malleable iron. The insulating part is a bronze or steel bolt, heavily coated under pressure with non-conducting material, the head of which fits closely into a recess at the top of the protecting casting, and is firmly held there by a screw cap. These bolts are interchangeable throughout, and can be slipped in or out at any time. When it is desired to bring a feeder into the line, the insulating bolt is slipped out and a metallic "feeder plug" (Fig. 73) of exactly the same size takes its place, thus throwing the whole hanger into circuit, and allowing an insulated feeder wire to be attached to it in exactly the same way as an ordinary span wire would be. This is the type of apparatus which has been adopted for the Dublin, Bristol, Coventry, Leeds, Isle of Man, Port Elizabeth, Brisbane, and Capetown electric tramways, etc., etc.

A special tool, Fig. 74, is used in putting up "West End" straight

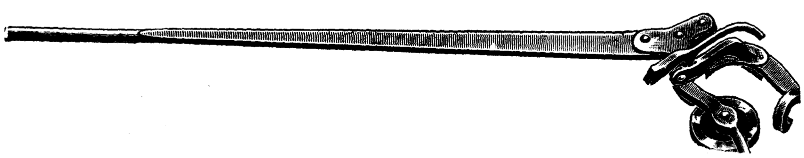


FIG. 74. SPECIAL TOOL FOR PUTTING UP "WEST END" STRAIGHT LINE HANGERS.

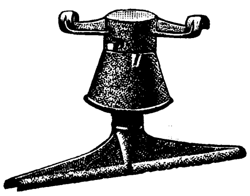
line hangers, and much facilitates the labour of erection. The casting is held in the fork at the top of the tool. The span wire fits into the groove of the wheel, and a single movement of the lever snaps the wire into position.

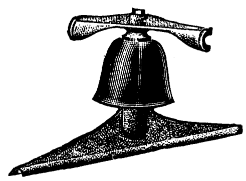
By the use of this "West End" type of apparatus the span wires can be erected, and the castings inserted at the fixed points of suspension, before the insulating material is brought on the line. Ears can be soldered to the trolley wire, and attached to the insulator afterwards, and there is a minimum of leakage through moisture. As an illustration of the care taken to supply each need, the "spring bridge" insulator, used under bridges and elevated railway structures and in tunnels, may be instanced (Fig. 71). As the fixture is, of necessity, rigidly attached to the structure above the line, a yielding support is provided in order that the trolley wheel, at high speed, may not strike a point without flexibility, and have a tendency to jump the wire. The spring is protected by a galvanised iron

case, and the insulating bolt within has a fluted metal covering, which preserves the insulation from injury by chafing, and prevents the bolt turning.

The use of high-class line material greatly facilitates both construction and operation, and in no part of the equipment can a little additional expense be incurred with such good reason. The cost of these supplies are so insignificant when compared with the total investment involved in an electric tramway installation, and their importance so great, that there is no excuse for not employing the very best material.

It will be noted that the makers of both the above types of apparatus endeavour to bring span wire and trolley wire as closely together as possible.





Figs. 75 and 76. Old-Type Straight Line Insulators.

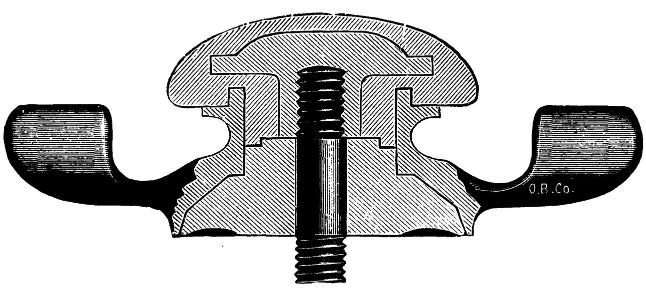


Fig. 77. Cap and Cone Insulator.

Earlier styles (Figs. 75 and 76) did not possess this virtue, the span wire being led over the top of the insulator. Experience quickly showed that it was an error to separate span and trolley wire more than absolutely necessary.

Many other types of insulated suspension devices are employed, but in general principle they correspond with those already described. Fig. 77 shows a straight line insulator in section, in which the strain is taken by malleable iron or brass castings, which spread out sufficiently to protect the insulation. A cap of insulating material, from which projects a screw stud, fits closely over the top of the casting, and the recess beneath receives a cone of the same insulating substance, through the centre of which the stud

passes. When the trolley wire ear is screwed up on the stud, the whole is bound tightly together.

To connect the trolley wire with its insulated supports, ears or clips are used. For efficiency, durability, and smooth running, nothing quite equals an ear soldered to the trolley wire, and soldered ears are almost indispensable at curves or points of heavy strain (Figs. 78 to 81). However, it takes skilled labour and quite one-third longer in time to erect a line using soldered ears throughout. The blowpipe should not be used in erecting a trolley wire with soldered ears, but instead, heavy grooved soldering irons ought to be employed. The use of the blowpipe softens the wire, and renders it liable to break.

A trolley wire must be "anchored" at least every mile of straight line, and always at either end of every curve. Special ears (Fig. 79) are provided to which the anchor wires can be readily attached. Special ears

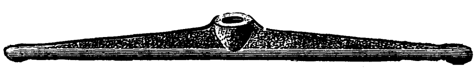


Fig. 78. Soldered Trolley Wire Ear.

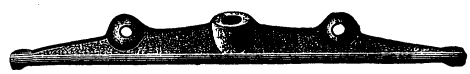


Fig. 79. Anchor Ear.

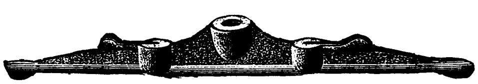


Fig. 80. Splicing Ear.

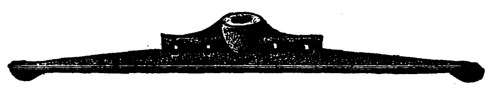


Fig. 81. Feeder Ear.

are also used for joining together lengths of trolley wire (Fig. 80). Joints should always be made at fixed points of support. Combination anchor and splicing ears are also used. Other ears are used for points where it is desired to make connection with feeders (Fig. 81). Trolley wire soldered ears are made 7in., 9 in., or 15 in. long. The perfect mechanical ear has not yet been evolved, although improvements are constantly being made. The difficulty is that all mechanical ears interfere more or less with the smooth under-surface of the trolley wire; and any obstruction, however slight, to the passage of the wheel is a disadvantage. The "Badger" mechanical ear is simple and effective. (Fig. 82.) It is composed of two interlocking plates of malleable iron or bronze, which, when placed together, leave a groove into which the trolley wire is clamped by the wedge-shaped stud of the insulator being forced into the jaws formed by the upper portion of the two plates. A pin through the stud holds the ear and stud together. The same clamping principle is also applied in various hinged ears, a screw stud set in the insulator being substituted for the wedge, and the pin being

dispensed with. Other similar types have their clamps held together by screws. The "Anderson" mechanical ear, Fig. 83, is composed of a bronze casting, grooved along its lower surface to fit the trolley wire, and a plate of hard rolled copper or iron bent to fit over the trolley wire, and furnished with eyes which close over slotted projections on the casting. The whole is bound together by forcing the eyes into the slots by the small screw bolts at the top of the casting. A special clamp is used to force this plate into position and hold it until the screws have been set up.

The number of mechanical clips is legion, but none are quite as efficient as the soldered ear. Mechanical ears are good or bad in proportion to the extent to which they interfere with the smooth running of the trolley wheel, and necessitate bending of the wire. The latter is always a mistake,

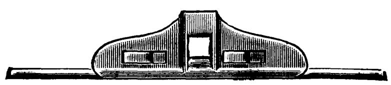


FIG. 82. "BADGER" MECHANICAL EAR.

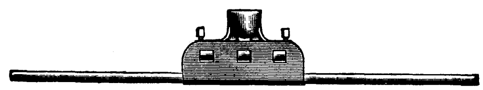


FIG. 83. "ANDERSON" MECHANICAL EAR.

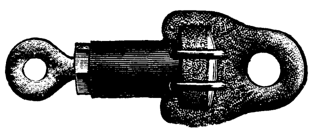


FIG. 84. "BROOKLYN" STRAIN INSULATOR.

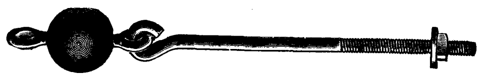


FIG. 86. GLOBE POLE INSULATOR.

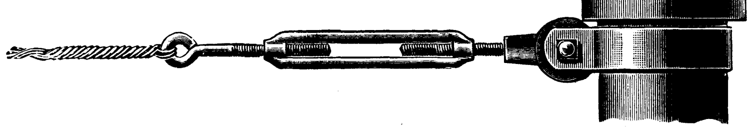


FIG. 85. "KING" INSULATED TURNBUCKLE AND POLE STRAP.

because, if it happens that the position of an ear has to be changed, a kink is left in the wire. It is also an error, frequently made in early days, to allow any play or joint between the insulator and the ear. Double insulation is a feature of first-class overhead line work. This is effected by supplementing the insulated trolley wire supports by an additional insulator at the pole-head, where cross suspension is used.

The "Brooklyn" strain insulator and turnbuckle combined is the best device for this purpose (Fig. 84). Aside from its insulating qualities, a pair of the regular size will take up 6 in. of slack in the span wire. This is extremely useful in adjusting tension when the span wires have become stretched by constant use. A larger size is made for use at terminals, and for corner poles, to which a number of curve pull-off wires are carried.

The "King" insulated turnbuckle (Fig. 85) is a device of similar

nature, and strain insulators of various types are also frequently used. All globe (Fig. 86) and strain insulators are constructed so that should their insulation be entirely destroyed, their interior metallic parts would interlock and prevent the line falling.

In cases where the trolley wire is supported by bracket arms from side poles, double insulation is obtained by the use of a tube of insulating material within the sleeve of the bracket arm hanger (Fig. 70). It is a mistake to fix bracket arm insulators to predetermined points of the bracket. A sleeve which will slide along the projecting arm easily should always be used, as nothing but observation of the trolley wheel as it passes under each

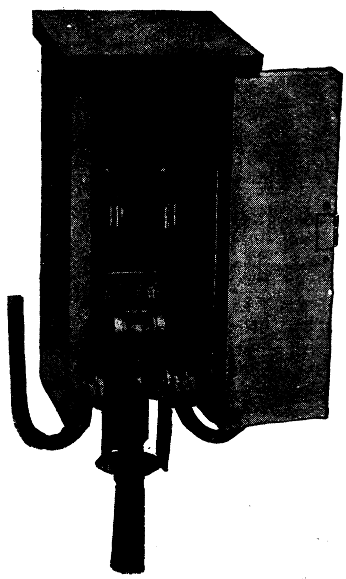


Fig. 87. Section of Switch Open.

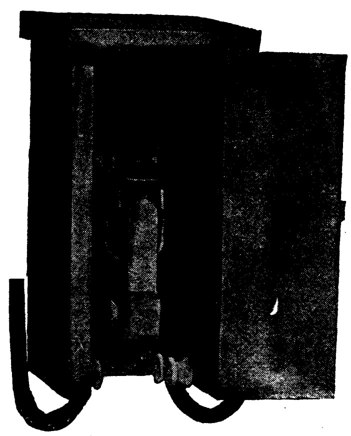


Fig. 88. Section of Switch Closed.

bracket can determine the exact point at which the hanger can be most advisably fixed.

A trolley wire of any considerable length should always be divided up into sections, so that an accident could not cause the whole line to be thrown out of service. For this purpose special section insulators are used. Connection between the two sections of trolley wire is made or broken through a switch contained in a wooden or iron box on the nearest pole (Figs. 87 and 88). The earlier types of section insulators were made of brass sections insulated from each other by mica. The insulation of the later forms, shown in Figs. 89 and 90, is effected by bolts similar to those used in the "West-End" hangers hereinbefore described, and the most improved type

has the great advantage of being "straight under-running," allowing the trolley wheel to pass under it without the slightest "dip." This device is strong and durable. The wooden piece between the terminals is renewable, and can be changed while on the line. A convenient clamping device renders it possible to leave enough trolley wire coiled on top of the section

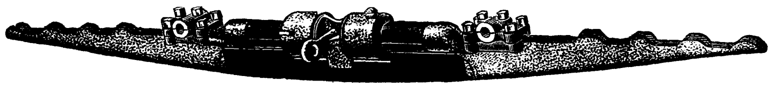


FIG. 89. "ÆTNA" SECTION INSULATOR.

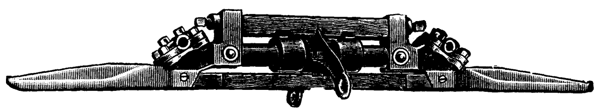


FIG. 90. "ÆTNA" SECTION INSULATOR. (STRAIGHT UNDER-RUNNING.)

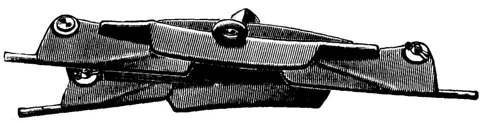


FIG. 91. TWO-WAY AERIAL FROG. (STRAIGHT UNDER-RUNNING.)

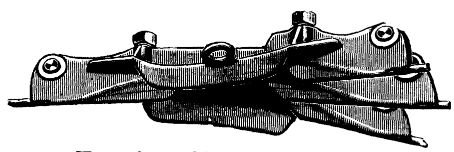


FIG. 92. THREE-WAY FROG. (STRAIGHT UNDER-RUNNING.)

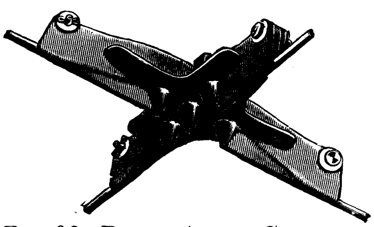


FIG. 93. RIGHT ANGLE CROSSING. (STRAIGHT UNDER-RUNNING.)

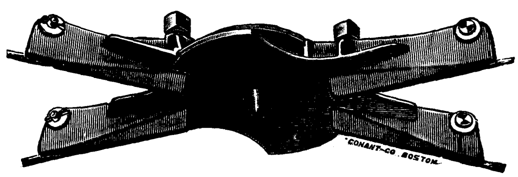


FIG. 94. DIAGONAL CROSSING. (STRAIGHT UNDER-RUNNING.)

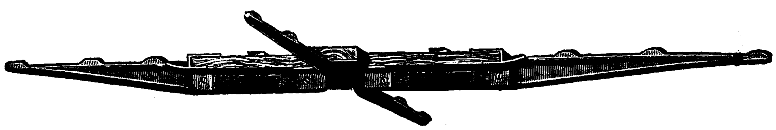


FIG. 95. INSULATED TROLLEY WIRE CROSSING.

insulator to allow of its being let out to repair the line in case of a break. Another part of this combination clamp holds the feed wire in such a way as to obviate the necessity of stripping the insulation from the wire except at the part held by the clamp. By this arrangement the feed wire is left insulated from the poles to the section insulators, and between the lines (where there is a double track).

Frogs and crossings are also inserted in the trolley wire, closely following the points and crossings in the track itself. The later types, Figs. 91 to 95, are much improved over those used a year or two ago (Fig. 96). All the newest styles have the "straight under-running" feature, and require no solder, the trolley wire being clamped into the casting. In all cases the trolley wire is carried over the casting, so that the excessive wear at these points is taken by the heavy metallic flanges, and not by the conductor. Right and left hand, **Y** and three-way frogs are

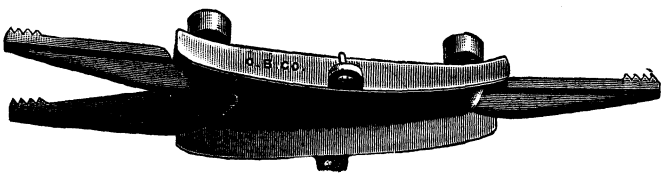


Fig. 96. Old-Style Two-Way Frog.

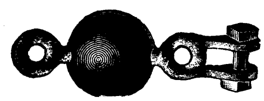
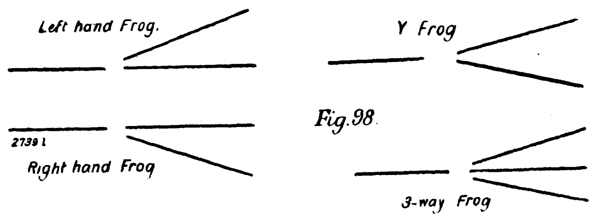


Fig. 97. "Globe" Frog Pull-Off.



Right and Left-hand, Two and Three-way Frogs.

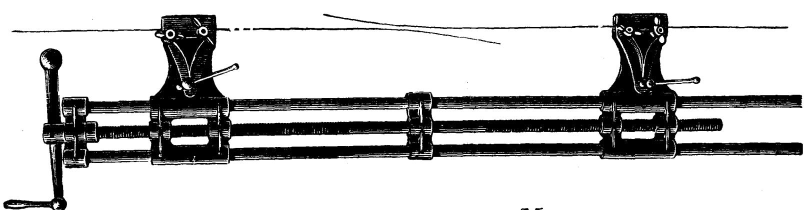


Fig. 99. Wire-Stretching Machine.

used, and they are insulated and supported by frog pull-offs (Fig. 97). The operation of right and acute angle crossings is easily understood from the illustrations (Figs. 93 and 94), and an insulated crossing (Fig. 95) is employed whenever one trolley wire crosses another from which it must be insulated. Fig. 98 is a diagram, showing the position of the arms of the various styles of frog. The wire-stretching machine (Fig. 99) is an extremely useful tool in all cases where it is necessary to take the tension off the trolley wire, as in splicing, or inserting switches, frogs, &c.

The terminal insulator (Fig. 100) is generally employed at the terminals of a trolley wire line, or wherever heavy strains are to be withstood. The

terminal clamp (Fig. 101) is used wherever a simple loop in the wire is not sufficient to take the strain. The "Come Along" clamp (Fig. 102) is used when the trolley wire is strained up taut by means of a block and fall. In case of the trolley wire being broken by any accident, splicing tubes are used to join it again. Fig. 103 shows such an appliance. It consists of two sleeves with recesses in each screwing on to a central piece. The two sleeves are first passed over the broken ends of the wire, and a special threaded plug, fitting the recess in the sleeve, is screwed on to each end. The centre piece being then screwed upon the sleeves, the whole is held firmly together. Other tubes are made in one piece, with a slightly expanded central chamber, in which the broken ends of the trolley wire are clamped by the aid of wedges and solder (Fig. 104). The essential feature of a good splicing tube, beyond its affording a sure fastening readily

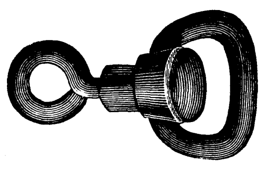


FIG. 100. HEAVY TERMINAL.

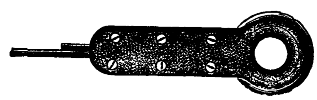


FIG. 101. TERMINAL CLAMP.

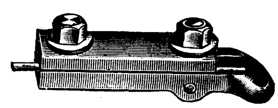


FIG. 102. "COME ALONG" CLAMP.

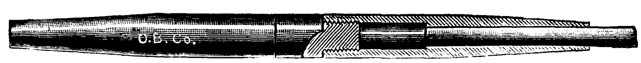


FIG. 103. THREADED TROLLEY SPLICER.

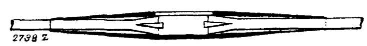


FIG. 104. WEDGED SPLICING TUBE.

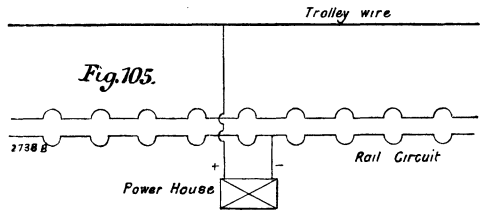
and quickly applied, is that it shall as little as possible increase the diameter of the wire, or interfere with the even under-surface upon which the trolley wheel runs.

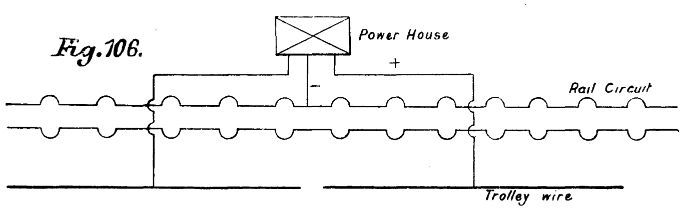
TABLE XXIV.—APPROXIMATE WEIGHTS OF INSULATORS.

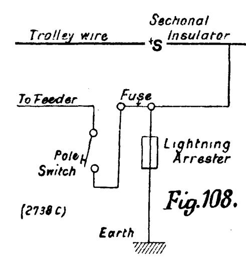
	lb.		lb.
Ear for pull-off or hanger	$\frac{2}{3}$	to	$1\frac{3}{4}$
Pull-off, without ear	2	,,	$2\frac{3}{4}$
Straight line hanger, without ear	$2\frac{3}{4}$	,,	—
Bracket arm hanger, without ear	5	,,	—
Insulating bolt	$\frac{3}{4}$	,,	—
Double insulating bracket arm hanger sleeve	$2\frac{1}{3}$	,,	—
Brooklyn strain insulator	$2\frac{1}{2}$	,,	$5\frac{3}{4}$
Globe strain insulator	1	,,	$2\frac{1}{4}$
Section insulator	12	,,	—
Frog or crossing	6	,,	8

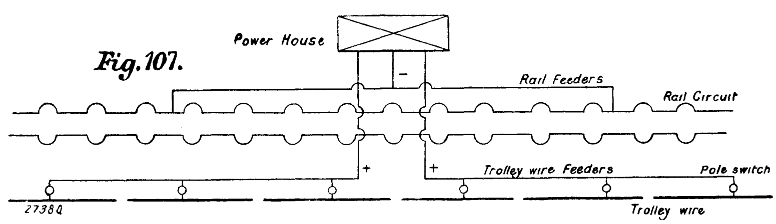
If a line exceeds three or four miles in length, feeders become necessary. In a short line with few cars running, the trolley wire usually

suffices to carry the current (Fig. 105), and it would only be required to connect the overhead conductor to the positive terminal of the generator, the negative being connected to the rails. If the line be not too long, one or two feeder connections suffice, especially on a suburban road. Fig. 106 is a diagram of such an arrangement. In this case the line is shown divided up into only two insulated sections, and in case of anything happening to one section, it could be entirely isolated by cutting out









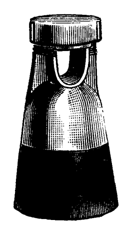


Fig. 109.

Figs. 105 to 107. Diagrams of Feeder Circuits. Fig. 108. Diagram of Lightning Arrester Circuit. Fig. 109. "Ætna" Brass Cap Feeder Insulator.

the feeder at the power-house. Where the overhead line must be much more frequently subdivided, as in city streets, Fig. 107, sectional insulators are generally inserted every quarter of a mile or less. It then becomes too costly to have a separate feeder for each section, and pole switches are inserted wherever the feeder is connected to the trolley wire, so that each section can be cut out by opening the pole switches (Fig. 108).

Lightning arresters and fuses are also generally contained in the box containing the switch. Fig. 107 also shows return feeders, which have to

be put in when the current-carrying capacity of the rails is overtaxed. Nothing explicit need be said of laying underground feeders, as there is practically no difference between these and underground electric light mains. The only essential is that they be well insulated and protected, as one of the circuits is already to earth. From bad feeder insulation, very appreciable losses may result. As it is known where feeders are going to be tapped, the practice of using armoured cables laid directly in the ground is good.

In America, until quite recently with few exceptions, all feeders have been overhead, and consist of solid or rope-stranded copper wires, insulated with two or three layers of braiding saturated with waterproof compound, and hung from specially shaped insulators, of which several styles are employed. The best has a metallic yoke into which the feeder cable is laid and firmly held by a screw cap (Fig. 109). This greatly economises labour in the erection of an aerial feed wire.

A few words may be said as to how the feeder sections may be determined so as to prevent the loss in potential exceeding, say, 10 per cent. under ordinary conditions. A plan is laid out showing the position of the various lines, the power-house, and the section insulators. The service, number of cars, their headway, speed and weight, the gradients, and the position of power-house being known, the cars are distributed over the various lines and in places which would require most power. From experience, the efficiency of motors and gearing is known, so that the calculated horse-power at the axle of each car can be transformed into amperes. If there are no stiff grades, an allowance of from 15 to 25 amperes per motor car, according to size, average speed, and whether trailers are used or not, is a safe figure in calculating feeders at a pressure of 500 volts.

For a rapid estimate, the following Table may be useful for ascertaining approximately the amount of copper in the feeders. Fifteen per cent. drop in voltage is assumed, and for headways under seven minutes 25 amperes per car is allowed, 30 amperes being taken for headways exceeding seven minutes. Owing to the very heavy currents used in electric railway work, feeders very naturally have to be very large. The heating effect of the current and the power wasted in the conductors is inversely proportional to their sectional area, the initial cost varying proportionately to the section. In determining the sizes of feeders necessary, a very large number of factors enter into consideration. Some of these are unimportant, and their consideration would lead to needlessly involved calculations. Certain

quantities such as the electro-motive force, the constant for resistance of the overhead and return circuit, the ratio of interest and maintenance of feed wires, and the cost of fuel for power, are most important and vary according to the locality. Between the two extremes, that is to say, between the minimum initial cost of feed wires and the minimum of power wasted in them, there lies a mean economical area which is given by Lord Kelvin's Law, which says that "the most economical area is that for which the annual cost of energy lost just equals the annual interest on the capital invested." In the case of a railway circuit it must, however, be borne in mind that in many cases where the line extends some distance beyond the power station, the drop in voltage, which, according to Lord Kelvin's Law, would give the most economical feeders, is too large, and would cause the speed of the motors and the lights in the car to run too low.

TABLE XXV.—Giving Amount of Copper for Feed Wire in Pounds, for Length of Track Miles.

Headway Minutes.	1.5 Miles.	2 Miles.	2.5 Miles.	3 Miles.	4 Miles.	5 Miles.	6 Miles.	7 Miles.	8 Miles.	10 Miles.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
3	310	1,716	3,412	6,506	13,756	27,343	45,820	72,595	109,365	202,927
4	510	1,361	2,703	5,159	10,938	19,439	37,041	53,456	79,378	152,731
5	510	1,079	2,145	4,095	8,673	15,404	26,724	43,213	65,620	123,009
6	405	857	1,701	3,245	6,878	13,672	23,327	38,278	52,039	103,710
7	321	857	1,701	2,574	6,878	13,672	21,197	31,177	44,858	89,074
8	405	857	1,701	2,574	6,878	13,672	21,197	34,318	49,387	93,562
10	405	679	1,349	2,041	5,458	10,842	16,406	27,215	39,221	76,366
12	405	679	1,071	2,041	4,327	8,598	16,406	21,588	32,788	61,733
15	405	679	1,071	1,618	3,431	6,823	13,009	19,140	28,261	49,026
20	405	679	1,071	1,618	2,721	5,407	8,406	15,159	21,874	39,878

In large systems the overhead line is always divided into insulated sections, each one fed by a special feeder. It is very useful to connect these various sections by safety fuses, generally consisting of a No. 12 B. and S. gauge copper wire. By this means the load on the feeders and sections is equalised, and the feeders are made to help each other. Feeders running parallel to each other, but which feed into different sections, are also connected by means of copper wire fuses. Should a trolley wire come down, or any trouble arise in any one section, the fuses will go, and thus cut out the section. By this method great fluctuations of load on any one feeder are avoided, and the line potential kept steady. Besides this, the feeder loads are equalised, thus preventing the circuit breakers being thrown out, and the drop and loss on the line is greatly reduced.

A large street railway system would be divided up into separate districts, each one fed by one or more special main feeders from the power-

house. Each main feeder should be brought to the electrical centre of gravity of the district it supplies, and then branch off in either direction. This secures the best division. The power station itself should, from the electrical efficiency standpoint, be as near as possible to the electrical centre of gravity of the whole system. Of course this cannot be done in most cases, the location of the generating station being determined by other considerations, such as cost of land, transportation of fuel, presence of feed and condensing water, &c. Where aerial feeders have to be joined together, splicers, such as the one shown in Fig. 110, are employed. This can be used as a permanent or temporary connector. The halves of the splicer are placed over the abutting ends of the bare wire. The nut is then screwed on the tapered end of the splicer, which is slightly corrugated on the inside, thus securely clamping the wire. If a permanent splice is desired, solder

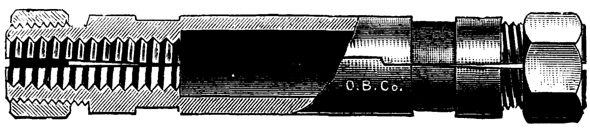
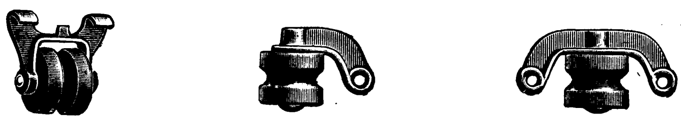


FIG. 110. FEEDER WIRE SPLICER.



FIGS. 111, 112, AND 113. GUARD WIRE HANGERS. PORCELAIN INSULATION.

can be poured through a slot provided for this purpose. A joint made in this way is but a trifle larger than the wire, and is of low resistance and great strength. Where guard wires are used to protect the trolley wire from being short-circuited by broken and fallen telegraph or telephone wires, they are insulated by small porcelain insulators (Figs. 111 to 113). The utility of guard wires is extremely doubtful, and although formerly used universally, many lines have discarded them. On the Continent a strip of wood is often attached to the upper side of the trolley wire whenever any danger from falling telegraph or telephone wires is apprehended.

So far as appearances are concerned, guard wires are very detrimental, as they more than double the amount of aerial line material. They are, of course entirely useless wherever the telephone and telegraph service employs underground conductors.

As already said, a trolley line in a city or town should be divided into quarter-mile, half-mile, or mile lengths, insulated from each other, and fed

by separate sets of feeders. Each such section should be supplied with a lightning arrester, choking coil and switch, all this apparatus being contained in a locked iron box fixed to one of the poles, and opened by a key carried by the employés of the company. Figs. 114 and 115 show such an arrangement, with overhead and underground feeders.

The "Ajax" arrester is much in use in America, and is of very ingenious construction. It consists of a series of fuses, such as are shown in Fig. 116.

The fuse consists of two pieces of No. 26 brass wire, each 3 in. long,

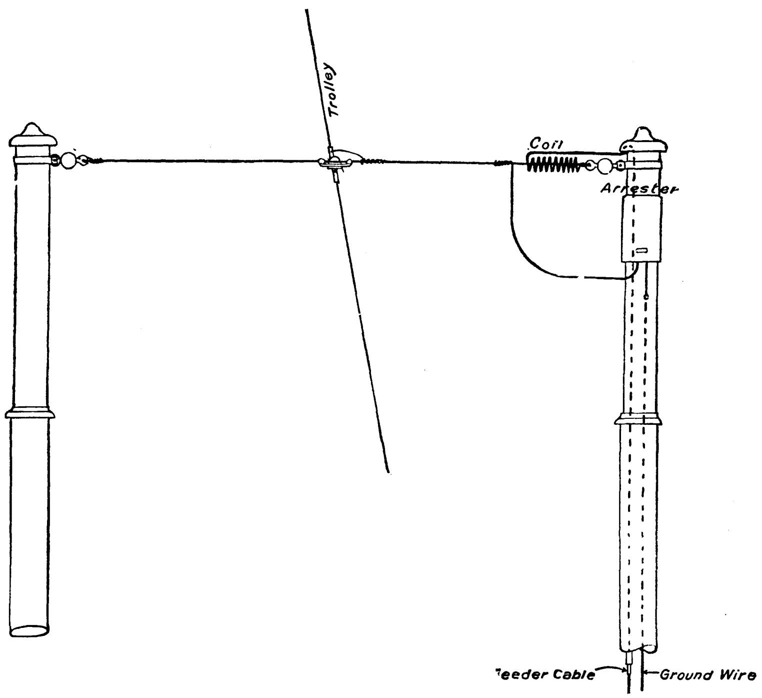


FIG. 114. DIAGRAM OF LIGHTNING ARRESTER CONNECTIONS—UNDERGROUND FEEDERS.

having a single silk insulation, and laid side by side for about 1 in., as do consecutive coils in an armature. This 1 in. lap of the wires offers abundant surface for the discharge gap, which is formed by the two thicknesses of silk, and amounts to little more than 0.002 in. Small pellets of a highly insulating wax secure these wires in the above position, and a small glass tube is hermetically sealed over this part of the fuse, to keep the dischargers clean and dry until used. The extreme sensitiveness of this part of the apparatus is made possible by its being called upon to act but once. The soft rubber plugs serve to hold the fuse in the corrugated cover of the

arrester, and the bare ends of the wires project through the cover, ready to be brought into contact with the line and ground terminals. Into the back of the case containing the fuses, two strips of metal are fixed, one a plain flat strip to which one end of each fuse is connected, the other a U-shaped

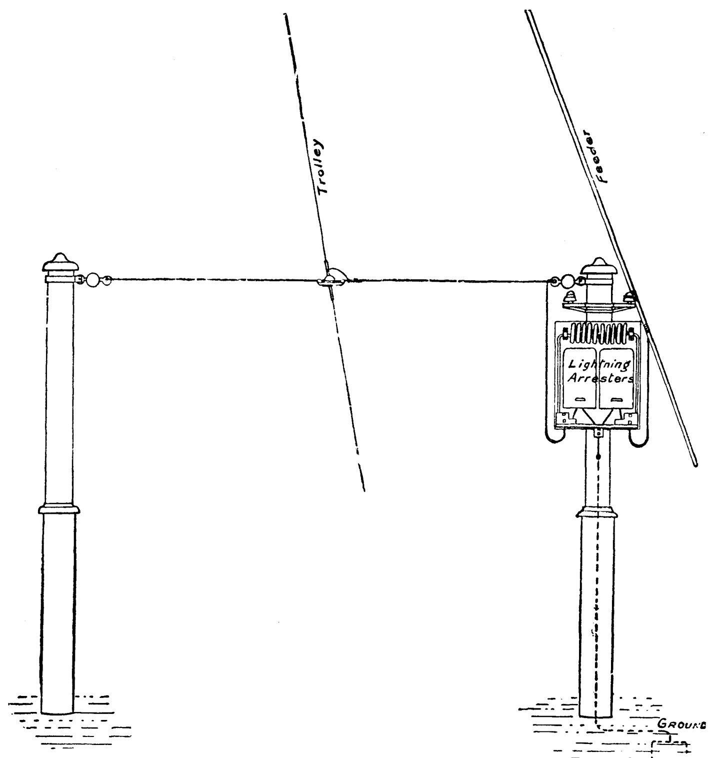


FIG. 115. DIAGRAM OF LIGHTNING ARRESTER CONNECTIONS—OVERHEAD FEEDERS.

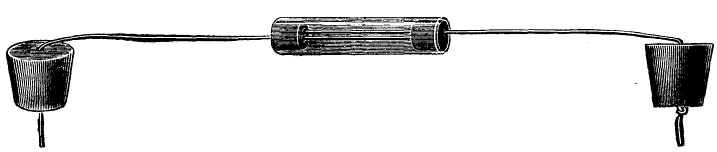


FIG. 116. "AJAX" LIGHTNING ARRESTER FUSE.

strip into which the remaining end of the fuse projects, contacts being made between it and the U-shaped strip by means of a carbon ball resting on the projecting end of the fuse. When the arrester is assembled and in position, only the top fuse is in parallel on the circuit ready for action. The static discharge will short-circuit the line through the fuse, which is at once utterly destroyed, allowing the carbon ball to drop, and putting the second

fuse in circuit. This type of arrester has proved successful on lines up to 1,000 volts.

Pole boxes are cast iron, asbestos-lined, and so constructed as to exclude rain. Fig. 117 shows the more general form of pole arrester. In

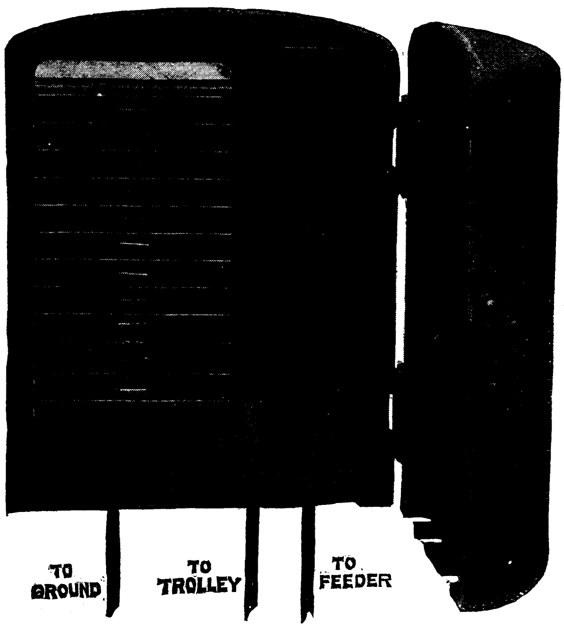


FIG. 117. POLE LIGHTNING ARRESTER WITH CHOKING COIL.

this the choke coil is contained in the arrester box; but it may be made by turning the insulated side feed used as span wire on itself a sufficient number of times to make the choke coil, thus making a cheaper construction and a smaller pole box.

CHAPTER VI.

ERECTION OF THE TROLLEY-WIRE.

WHERE cross-suspension by means of a span wire is used, the weight of the span wire, and of the one or two trolley wires, and of the hangers, frogs, &c., which it supports, must be borne in mind. As the necessary calculations are long and tedious, the following very interesting Tables (XXVI., XXVII., and XXVIII.), resulting from a careful and extended series of dynamometer tests, are inserted. These tests were made and the Tables compiled therefrom by Mr. F. A. Merrill, of New York. In all, the span of the trolley wire was taken at 125 ft. of No. 0 Brown and Sharpe gauge hard-drawn copper trolley wire (0.3249 in. in diameter). The span wire is $\frac{5}{16}$ in. in diameter and stranded, being composed of seven galvanised steel wires.

TABLE XXVI.—GIVING SAG ON TROLLEY-WIRE AND CORRESPONDING STRAIN FOR AN INITIAL MAXIMUM STRAIN OF 2,000 LB.

Temperature Fahr. deg.	Dip. ft.	Dip. in.	Strain. lb.
10	0	3.7	2,000
20	0	9.7	774
32	1	6	415
50	1	10	340
70	2	1	300
90	2	4	267
10	0	3.7	2,000
32	1	2	534
50	1	6	415
70	1	10	340
90	2	1	300
32	0	3.7	2,000
50	1	0	623
70	1	5	440
90	1	10	340

By the use of these Tables it is possible to determine the strength of the eye-bolts or pole straps to which the span wires are to be attached, when

TABLE XXVII.—GIVING SAG ON SPAN WIRE AND STRAIN ON SIDE POLES FOR TWO TROLLEY-WIRES 10 FT. APART.

Span in Feet.	Strain on Poles in Pounds.							
	500	800	1,000	1,500	2,000	2,500	3,000	3,500
	in.	in.	in.	in.	in.	in.	in.	in.
40	15.4	9.6	7.7	5.1	3.9	3.1		
50	20.8	13.0	10.4	6.9	5.2	4.2		
60	26.3	16.4	13.1	8.8	6.6	5.3	4.4	
70	31.9	19.9	15.9	10.6	8.0	6.4	5.3	
80	37.6	23.5	18.8	12.5	9.4	7.5	6.3	5.4
90	43.5	27.2	21.8	14.5	10.9	8.7	7.3	6.2
100	49.5	30.9	24.8	16.5	12.4	9.9	8.3	7.1
110	55.6	34.7	27.8	18.5	13.9	11.1	9.3	7.9
120	61.9	38.7	30.9	20.6	15.5	12.4	10.3	8.7

TABLE XXVIII.—GIVING SAG ON SPAN WIRE AND STRAIN ON SIDE POLES FOR SINGLE TROLLEY-WIRE.

Span in Feet.	Strain on Poles in Pounds.						
	500	800	1,000	1,500	2,000	2,500	3,000
	in.	in.	in.	in.	in.	in.	in.
30	7.8	4.9	3.9	2.6	1.9		
40	10.6	6.5	5.3	3.5	2.7		
50	13.6	8.5	6.8	4.5	3.4	2.7	
60	16.7	10.4	8.3	5.6	4.2	3.3	2.8
70	19.9	12.4	9.9	6.6	4.9	4.0	3.3
80	23.2	14.5	11.6	7.7	5.6	4.6	3.9
90	26.7	16.7	13.4	8.9	6.6	5.3	4.5
100	30.3	18.9	15.2	10.1	7.6	6.1	5.1
110	34.0	21.3	17.0	11.3	8.5	6.8	5.7
120	37.9	23.7	18.9	12.6	9.5	7.6	6.3

the minimum height of the trolley wire is known. This height is equal to the minimum height of the trolley wire plus the sag of the trolley and span wires determined by the Tables.

It is first necessary to ascertain what strain can be safely put on the trolley wire, in order that it may be strained only to such a point that at the lowest temperature to which the line will be subjected, the strain on the wire will not surpass the point of safety. In the case of hard-drawn No. 0 (Browne and Sharpe gauge) Lake Superior copper trolley wire, it is quite safe to allow 2,000lb. for the strain at the lowest temperature, but no more.

In case of span wires this must also be taken into account. It is quite

possible to calculate the sag strain, length of wire for span with given sag, and the effects of change of temperature. The curve affected by the trolley wire is that of a catenary. To simplify calculations, the catenary can be replaced by a parabola without great error. If the changes due to temperature are taken into account, an equation of the third degree is the result.

From the above Tables the following empirical formulæ based on the equation of the catenary have been worked out:

D = dip or sag in inches.
l = length of span in feet.
S = strain on poles in pounds.
t = number of degrees Fahrenheit between actual temperature and the temperature at which the strain is 2,000 lb.
T = tension on wire in pounds.

Span Wire Formulæ.

Cross-suspension single track $D = \frac{l}{S}\left(120 + \frac{l}{2}\right).$

„ „ $D = \frac{l}{S}(160 + l).$

Trolley Wire Formulæ.

$$T = \frac{7477}{D}$$

$$D = \sqrt{8.1t + 14}.$$

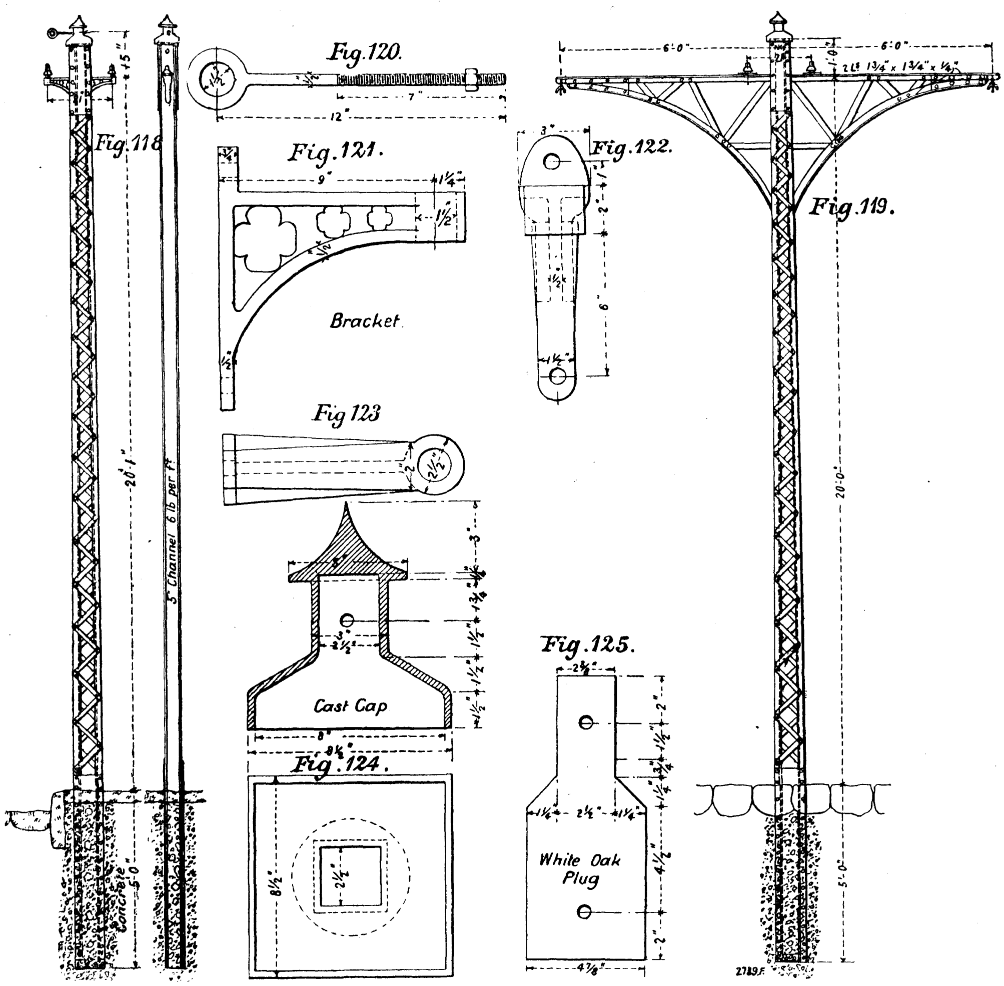
Table XXIX. gives the dimensions and weights of poles usually employed on American lines.

TABLE XXIX.—Giving Sizes and Weights of some Standard Types of Poles used in America on Electric Street Railways.

Material of Poles.	Length over All.	Diameter at Bottom.	Diameter at Centre.	Diameter at Top.	Approximate Weight.	Lateral Strain at Top withstood without Permanent Deflection.
	ft.	in.	in.	in.	lb.	lb.
Cedar wood	30	10	...	8	450	—
„	28	9	...	7	400	—
Square sawn Georgia pine ...	30	10	...	8	850	—
„ „	28	9	...	7	600	—
Three-section tubular iron ...	30	8	7	6	825-1,300	3,000-4,000
„ „ ...	30	7	6	5	600-1,000	2,000-2,500
„ „ ...	28	6	5	4	475-750	1,000-1,500
„ „ ...	27	5	4	3	350-525	800-1,000
Two-section tubular iron ...	26	6	...	5	500	1,500

All poles must be of at least such strength that when in position they will stand, without appreciable permanent deflection, side strains as follows:

	lb.		lb.
Double track, cross-suspension	1,500	to	1,800
Single „ „	1,000	„	1,500
Double and single bracket arm suspension	1,000	„	1,200



DETAILS OF LATTICE-WORK POLES.

The poles holding the pull-offs on curves should be of the strongest. Ordinary side poles must stand a direct strain of at least 500 lb. without deflecting more than 4 in. or 5 in. Their strength should be such as to carry, besides the weight of the trolley wire, the additional weight imposed when the wires are covered with ice and snow. Where wooden poles are used, the best quality is chestnut, cedar, or Georgia pine.

On rough country roads wooden poles are often left round, and when the line passes through villages they are sawn square, or into polygonal shapes and dressed smooth. The tops are coned, and from an economical point of view it is of the greatest importance to keep them well painted. Care is taken that the poles used are free from shakes, checks, or large knots.

Iron or steel tubular or lattice poles, Figs. 118 to 132, are more

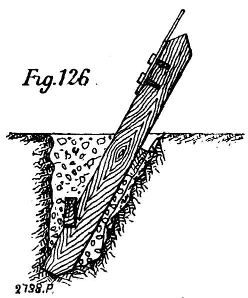


FIG. 127.

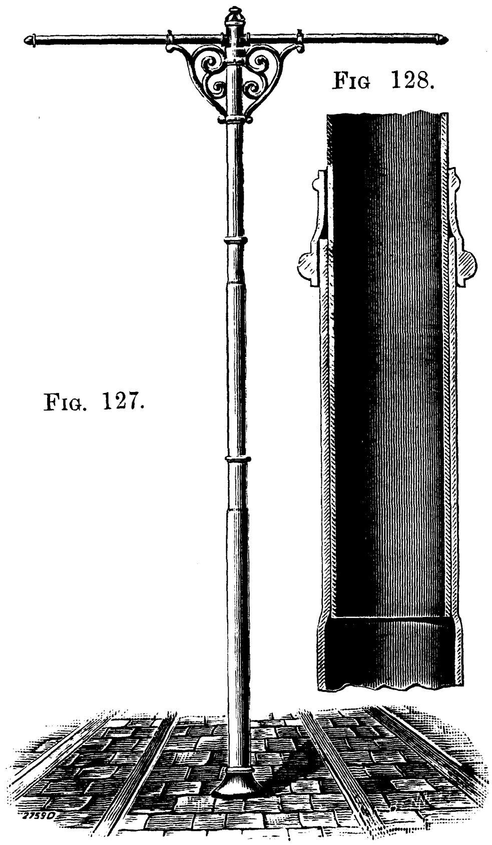


FIG 128.

FIG. 126. POLE OUTRIGGER ANCHORAGE. FIG. 127. TUBULAR STEEL, THREE-SECTION, DOUBLE-BRACKET-ARM POLE. FIG. 128. "S. S. S." (SOLID, SWAGED, AND SHRUNK) TUBULAR POLE JOINT AND ORNAMENTAL RING COVERING JOINT.

permanent and present a much better appearance. For city use they are exclusively used, and often handsomely ornamented. The tubular iron or steel pole, Fig. 127, is preferred to lattice construction in America, not only because of appearances, but because they stand strains equally well when applied in any direction. Round iron poles are sometimes reinforced by truss rods on the outside, but this arrangement is not desirable, and

should be avoided when possible. Poles are usually spaced from 120 ft. to 150 ft. apart, the average being 125 ft. The sag of the trolley wire in the warmest weather should not be allowed to exceed 15 in. to 18 in. The poles should be set 6 ft. deep in the ground, and surrounded by a foundation of concrete, 12 in. to 18 in. deep, a large flat stone being placed at the bottom of the excavation for the pole to rest upon, where base-plates are not used. Where wooden poles are employed, concrete is not used,

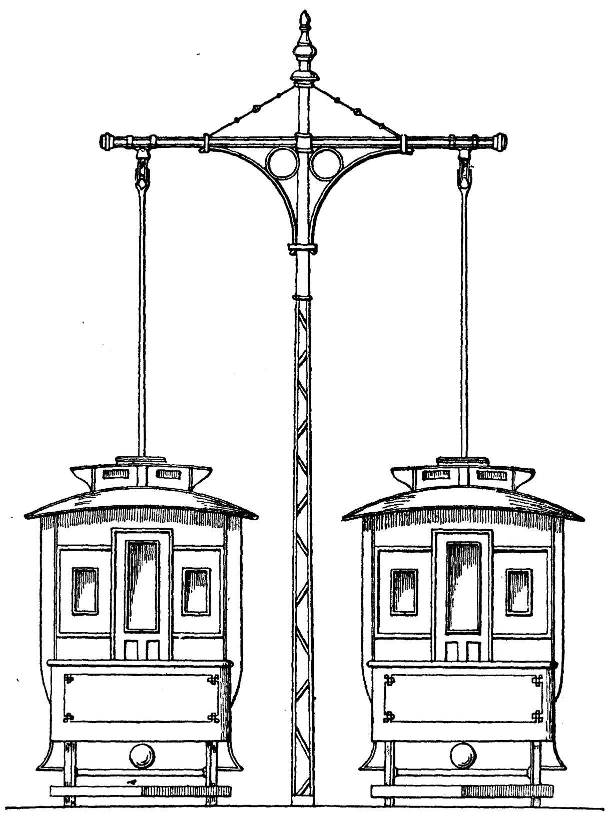
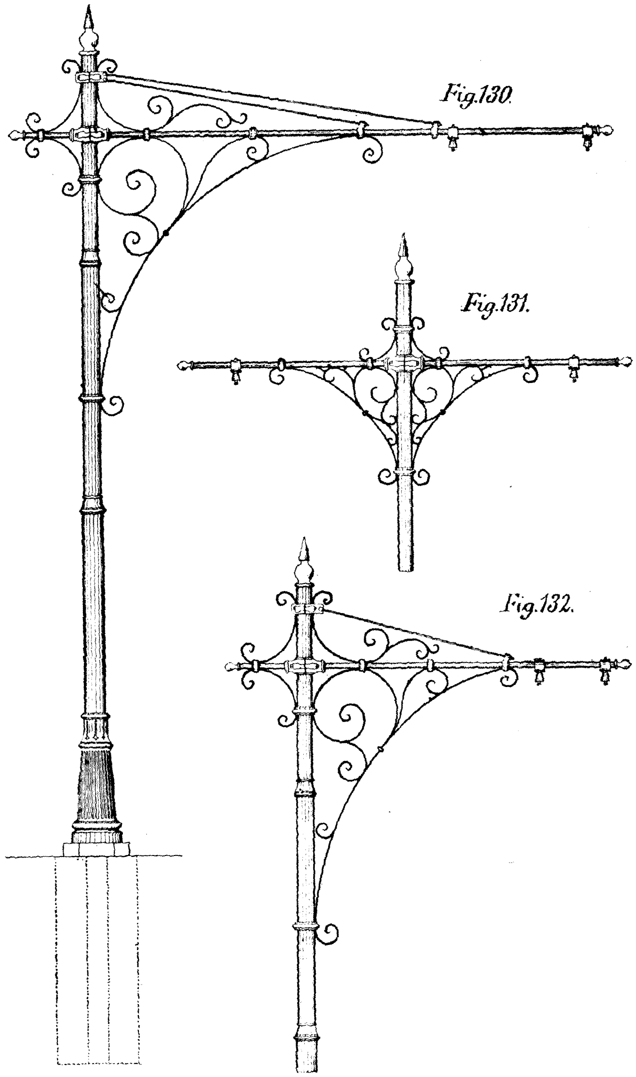


FIG. 129. GERMAN LATTICE-WORK POLE.

but care is taken to surround the pole with broken stone well tamped. If the soil be soft, guy wires are sometimes used.

On wooden side poles a rake of from 9 in. to 18 in. should be given away from the streets. Where iron poles bedded in concrete are used, this may be very much reduced, and should be from 6 in. to 9 in., according to the firmness of the ground. Poles supporting curves should be given an additional rake, and where possible should be heavily guyed. Guy out-riggers should be anchored about 5 ft. or 6 ft. in the ground, the top

extending about 6 ft. above the surface. They should be at least 8 in. or 9 in. in diameter, and rake towards the pole top, pointing directly to it (Fig. 126). The top of the poles should not be in metallic contact with the ground, or wires leading to it. The span and guy wires used consist

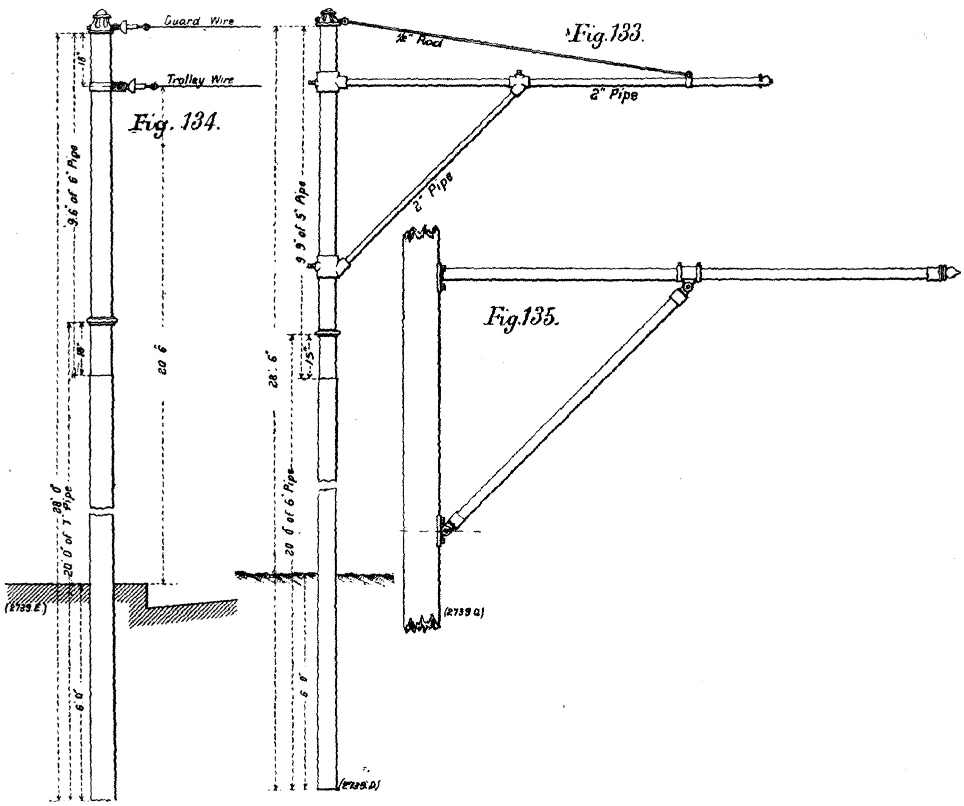


BRISTOL THREE-SECTION TUBULAR STEEL POLES AND BRACKETS.

generally of galvanised steel seven-strand signal wire, having from $\frac{1}{4}$ in to $\frac{5}{16}$ in. outside diameter. It is found that stranded wires can be handle much more easily than solid wires, and that they can be stretched mu more tightly, which is a great advantage. Near the tops of iron pol where span wire insulators are not used, a device is provided for insulat

the span wires from the body of the pole. Where guard wires are used, an extension is provided for fixing them. This is effected usually by inserting a wooden plug in the top of the pole; this plug is protected from moisture by an iron cap, and is often provided with a ratchet arrangement or bolt and nut for holding the span wires taut (Figs. 120, 124, and 125).

A very important point in the construction of tubular poles is to secure firm and permanent joints of the various sizes of tubes used in their



FIGS. 133 AND 134. ORDINARY SPAN AND BRACKET-ARM TUBULAR POLES.
FIG. 135. ADJUSTABLE BRACKET.

construction. This is usually done by swaging and shrinking the tubes one on the other (Fig. 128).

An illustration is given (Fig. 129) which shows, without needing any further description, one form of construction of the lattice iron and steel poles used in America and Europe.

Figs. 130, 131, and 132 show the poles and brackets adopted by the Bristol Electric Tramways, and which have been closely followed by the Dublin and Leeds lines.

Figs. 133 and 134 show ordinary American bracket-arm and side poles. Fig. 135 shows an adjustable bracket used on wooden poles.

The following very recent specifications for tubular iron poles for street railway purposes, drawn up by American experts, show what experience has proved to be the requirements of poles for use in connection with well-constructed trolley lines:

"Five grades of poles are called for, all of them 31 ft. long, to be set in the ground to a depth of 6 ft.

"No. 1 is to stand a lateral strain of 350 lb. applied to the top, without showing a temporary deflection greater than 6 in., and a strain of 700 lb. without showing a permanent deflection greater than ½ in.

"No. 2 is to stand a strain of 500 lb. without deflecting more than 6 in., and a strain of 1,000 lb. without more than ½ in. permanent deflection.

"No. 3 to stand a strain of 700 lb. without showing more than 6 in. temporary deflection, and strain of 1,200 lb. without permanent deflection of more than ½ in.

"No. 4 to stand a strain of 1,000 lb. without temporary deflection of more than 6 in., and 1,700 lb. without permanent deflection of more than ½ in.

"No. 5 to stand a strain of 2,000 lb. without permanent deflection of more than 6 in., and 2,600 lb. without permanent deflection of more than ½ in.

"The poles are to be as nearly round as possible. A difference of ⅛ in. between maximum and minimum diameter is all that will be allowed. They must all be as nearly uniform as possible, $\frac{1}{16}$ in. more or less than specified dimensions is all that will be allowed. One quarter of an inch is the greatest distance out of the true that will be allowed at the top of the pole. Ten per cent. of each lot of poles will be tested. Should three poles fail to come up to the specification, the engineer shall have the right to reject the entire lot. These poles will be dropped, butt foremost, from a distance of 6 ft. on to some solid substance three times, and must show no signs of telescoping or loosening in the joints."

Table XXX. gives the approximate quantities of line material used in overhead construction.

Fig. 136, which is a view of a square at Cincinnati, gives an admirable idea of the enormous amount of aerial wires existing in some large American towns; most, if not all, of these are telegraph, telephone, police, power, and lighting wires, the trolley wire being perhaps the least

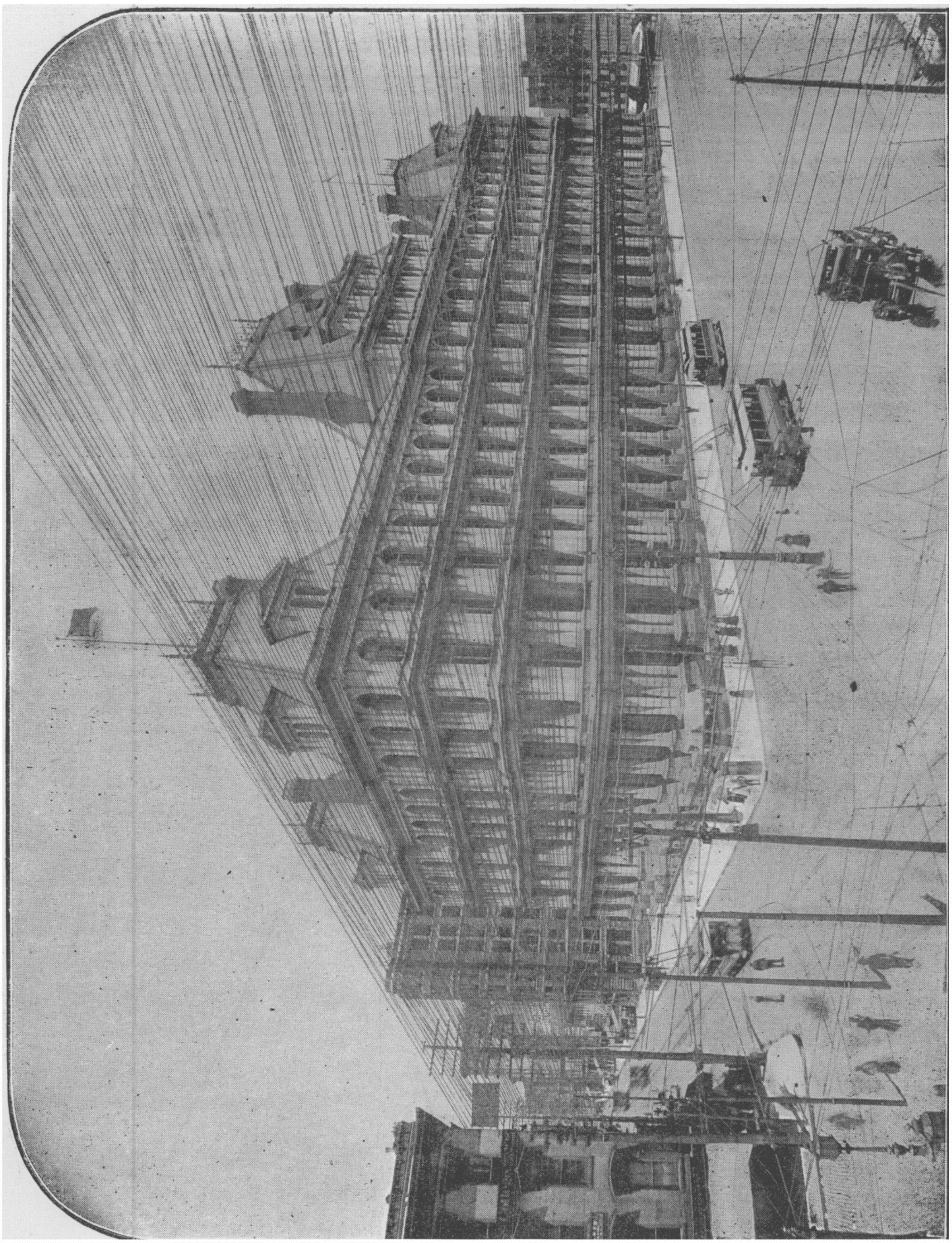


Fig. 136. Overhead Wires in Cincinnati.

objectionable. If the illustration were not a direct reproduction from a photograph, it might have been supposed that the degree of overhead obstruction had been exaggerated.

TABLE XXX.—NAMES OF PARTS AND APPROXIMATE QUANTITIES OF MATERIAL USED IN ONE MILE OF LINE CONSTRUCTION.

NAMES OF PIECES USED.	Cross Suspension.		Bracket Arm Suspension.		Simple Curve.		Branch Curve.		Anchorage.		One 200 ft. Turn-out.
	Single Track.	Double Track.	Single Track.	Double Track.	Single Track.	Double Track.	Single Track.	Double Track.	Single Track.	Double Track.	
Straight line insulator	46	92									
Single pull-off	..	..	..	..	3	3	3	5			
Double ,, ...	..	..	..	..	4	11	3	12	..	..	4
Bracket arm insulator	..	..	45	90							
Frog	..	..	..	..	..	..	1	2	..	..	2
Plain Ears or clips	45	90	44	88	5	10	5	15	..	..	4
Strain ,, ...	..	..	..	..	2	4	1	2			
Splicing ,, ...	1	2	1	2							
Strain Insulators	92	92	..	..	4	4	2	2	1	2	8
Insulated turnbuckle	..	..	..	..	4	4	2	2	1	2	
,, pull-off	..	..	..	..	..	..	2	6	..	..	4
Crossing	..	..	..	..	..	..	..	1	..	..	
Uninsulated turnbuckle	46	46	..	..	..	..	..		2	..	4
Number of Poles	90	90	45	45	2	2	2	2		2	2
Suspension wire in feet	3,000	3,000	..	..	800	800	800	800	500	500	100
Trolley wire in feet	5,280	10,560	5,280	10,560	..	..	..	..	..	200	200

CHAPTER VII.

ERECTION OF THE TROLLEY WIRE.

IN putting up an overhead line, the mode of procedure is generally as follows:—

A gang of men, consisting generally of one foreman and from six to nine men, begin their day's work by digging holes into which the poles are to be placed. Before commencing operations, the poles have been left along the road approximately in their proper places.

In the afternoon they proceed to erect them, and it has been found that such a gang will dig the holes for, and put up from 18 to 30 poles a day, according to the location and nature of the ground. When this has been done, the trolley wire gang follows. To hang the wire, a tower wagon is employed. The contractor generally uses an ordinary wagon on which he has erected a scaffolding having a platform with a railing round it on the top, and reached from the ground by means of a ladder, forming one or more of the sides of the scaffolding.

The street railway companies also use tower wagons, having adjustable ladders and platforms (Figs. 139 and 140), and sufficiently wide in gauge to stand astride of the tracks. When it is necessary to change position, the ladder and platform are let down. Beneath the driver's seat and on the body of the wagon, boxes are provided for storing the necessary tools. In front of the tower wagon, to draw which one horse is sufficient, there is a wagon drawn by two horses which carries the reel on which the trolley wire is wound in mile or half-mile lengths. The trolley-wire gang generally consists of one foreman, two drivers, three or four labourers, and two or three wiremen. Such a gang generally strings from three-quarters to one mile of double track cross suspension a day, and about three-quarters of a mile double bracket arm suspension a day, when mechanical clips or ears are used. If soldered ears are used, the same gang will, in the case of cross suspension, only do from one-third to three-quarters of a mile a day —a day's work consisting of 10 hours. The above, of course, only applies to straight-line work which can be done by day, and without having to adopt

special precautions so as not to hinder street traffic. A double curve on a double track takes one driver, three to four labourers, and two or three wire-men from two to four days to put up. Soldered ears or clips have always to be used on curve work, if it is to be well done. The *modus operandi* is generally as follows :

In case of cross suspension the cross wire is first put up and made

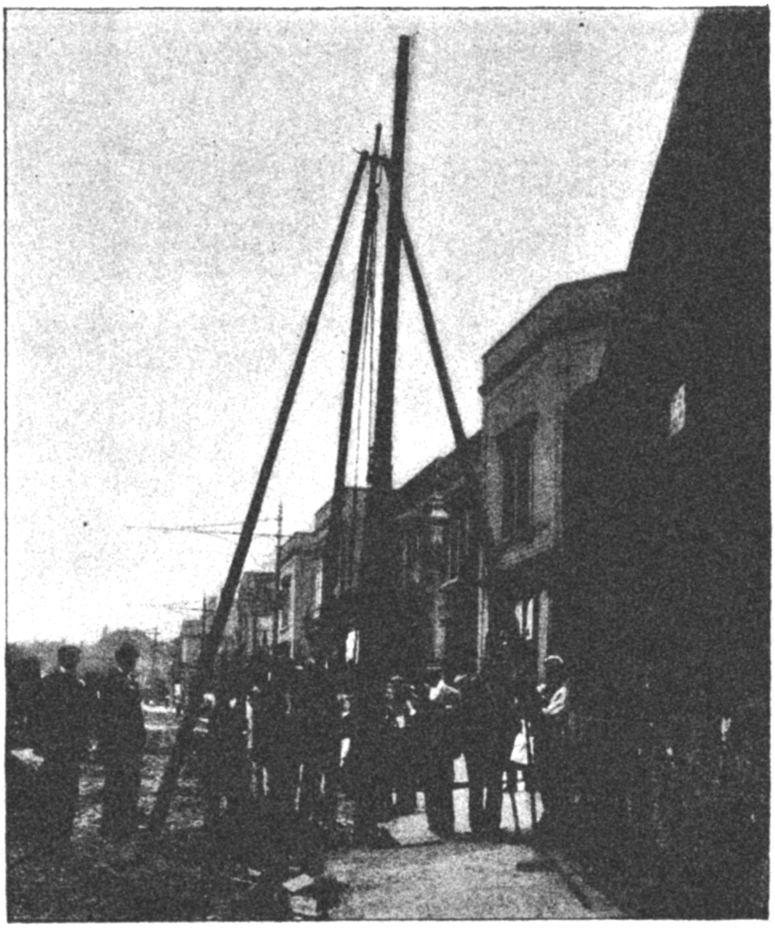


FIG. 137. PLANTING POLES ON THE BRISTOL ELECTRIC TRAMWAYS.

taut, being attached to the pole heads by means of strain insulators fixed to the poles by iron straps. An insulated turnbuckle is generally used for these points, although ratchet wheels are sometimes employed. The span wire is strained into position by fixing a single block and fall to the wire, by means of the "come-along clamp," already illustrated. The tension put on should be about 500 lb., and two men can generally

exert that strength. While still under strain it is attached to the turnbuckles, and any slight slack remaining is taken up.

When the span wires are in place the trolley wire is in turn hung. It is first anchored securely at the end of the line; from 800 ft. to 1,000 ft. are run out, or as much as can be done without too much hindering traffic. Hooks bent in S form, and made out of stiff iron

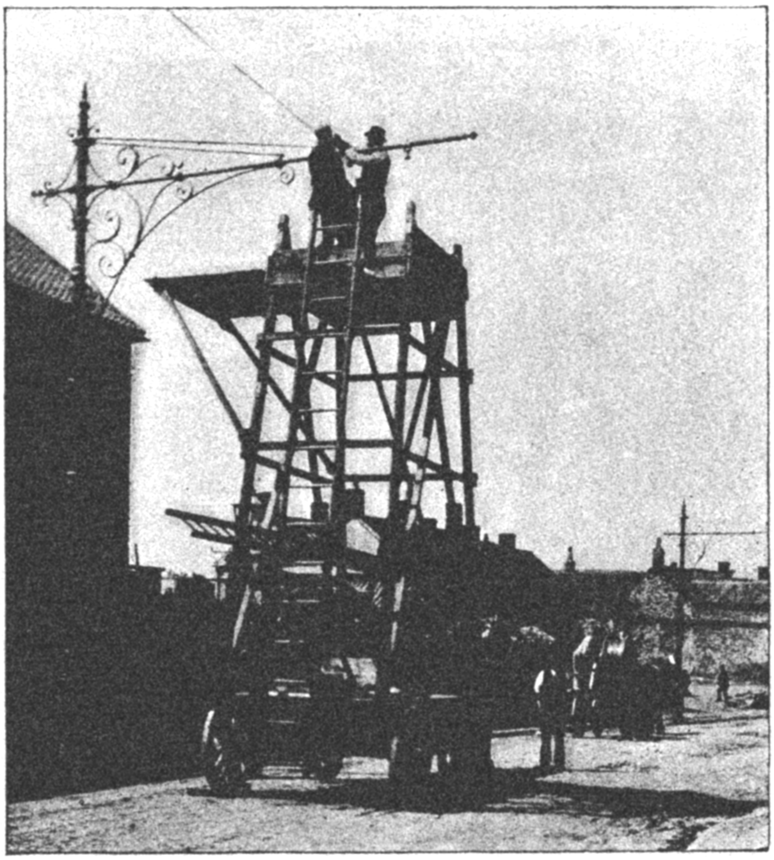


FIG. 138. ERECTING TROLLEY WIRE ON THE BRISTOL ELECTRIC TRAMWAYS.

wire, say a number 4 B.W.G., are hung over the span wires near the middle, and the trolley wire is raised over the tower wagon and hung in these hooks. At the end of the unreeled part of the trolley wire a "come-along clamp" is fixed, and by means of a double block and fall the part hung is pulled up tight and temporarily anchored. Another 1,000 ft. or so of trolley wire is then unreeled, and the same thing done until the reel has been run off. The reel is fixed on a very strong four-wheeled

reel wagon, generally drawn by two horses, and furnished with a brake by which the speed at which the trolley wire is run out can be regulated. The terminal anchorage is then definitely made to the nearest poles.

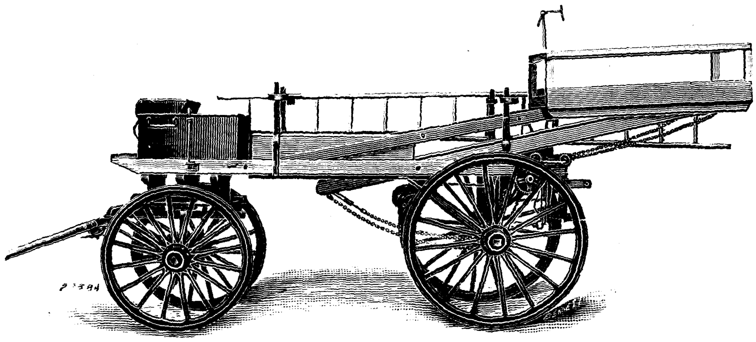


FIG. 139. COLLAPSIBLE TOWER WAGON.

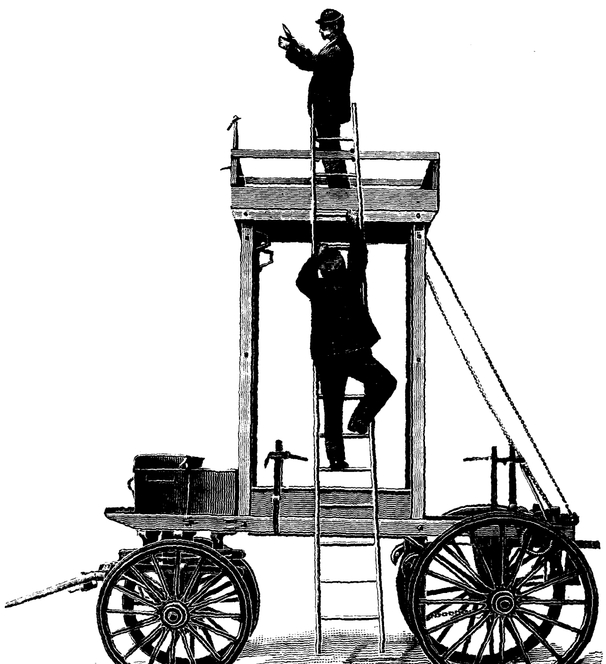


FIG. 140. COLLAPSIBLE TOWER WAGON.

Whenever a curve is reached, a permanent anchorage is made at each end, and as much slack allowed as may be needed to get around the curve. On curves the trolley wire should be placed slightly over the inside of the curve, and not over the centre. After this is done, the

ears or clips are either soldered or fixed to the wire. Great care should be taken in soldering, and each ear should be carefully inspected so as to ascertain that it is soldered to the wire along its whole extent, and that no rough pieces of solder project anywhere. Bad soldering is a frequent cause of trolley wire breaking or falling to the ground. A very heavy soldering-iron should be used, having a groove fitting half-way round the trolley wire. The iron used should not be too hot, and the strain must be taken off the trolley wire, when wiremen of the greatest experience are not employed, by a U-shaped clamp, catching hold of the trolley wire on either side of the ears while soldering. Every ear should fit every insulator used on the line. When the ears are soldered on they are screwed into the insulators, which are then sprung on the span wires by means of a special tool. For jointing the trolley wire every half mile or mile, special

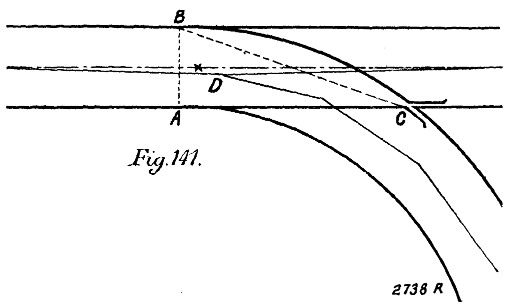


Fig. 141.

Location of Trolley Wire Frog.

ears or splicing tubes are used, and to draw the trolley wire taut at such points, and when putting in frogs or switches, a special wire-stretching machine is employed, which has already been illustrated.

A frog or line switch should not be put up in a line with the track points, but as shown in Fig. 141, that is to say, over the centre of gravity of the triangle A B C.

If on trial its position should not prove quite satisfactory, the trolley wheel should be chalked and run over it, so as to see where it runs off, and the frog set right. For this purpose turnbuckles are put on to the ends of the wire from which the frog is suspended.

All the preceding applies to putting up a line with bracket arm suspension, the only difference being that the hooks, through which the trolley wire is first passed, are hung on to the bracket arms instead of the cross wire.

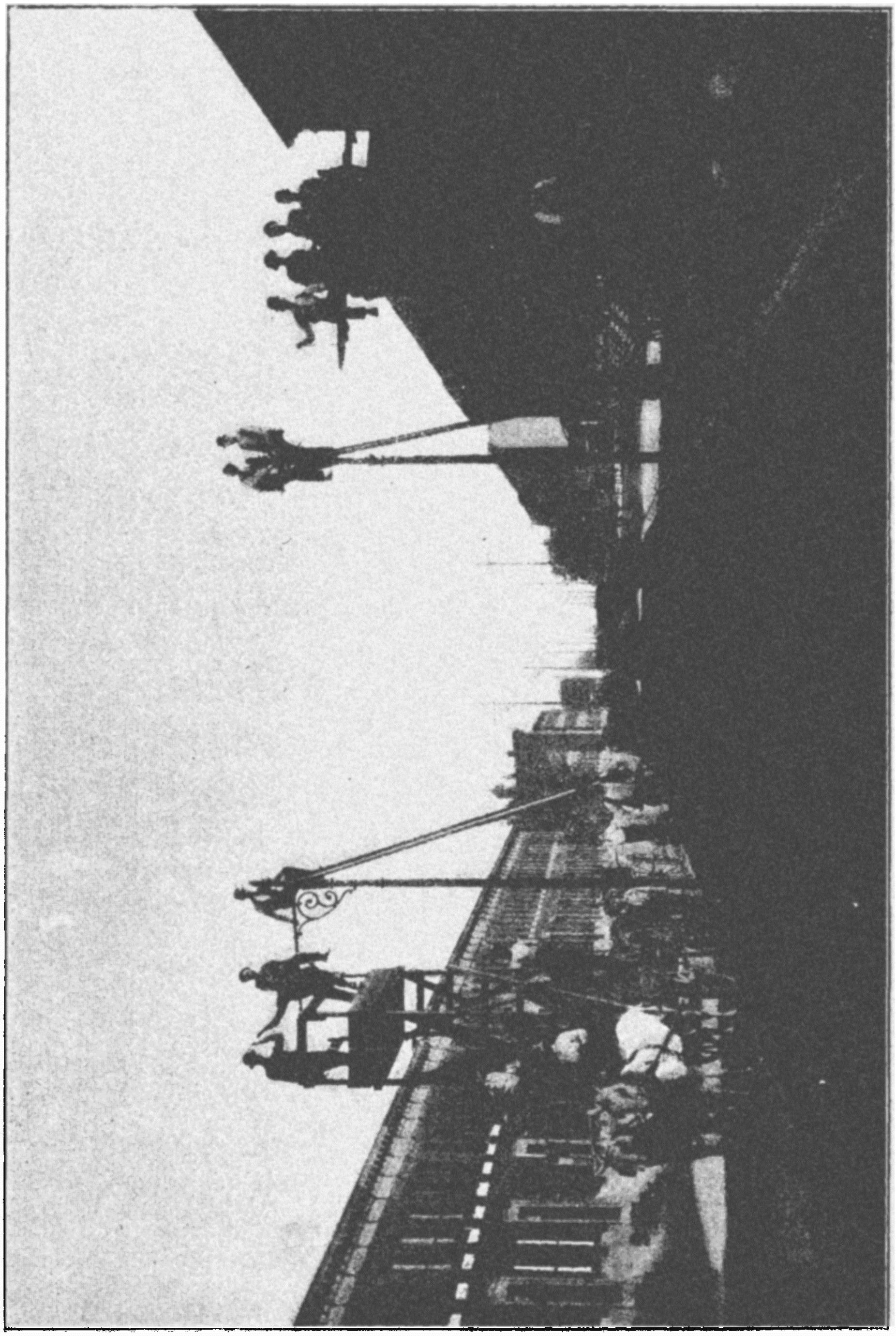
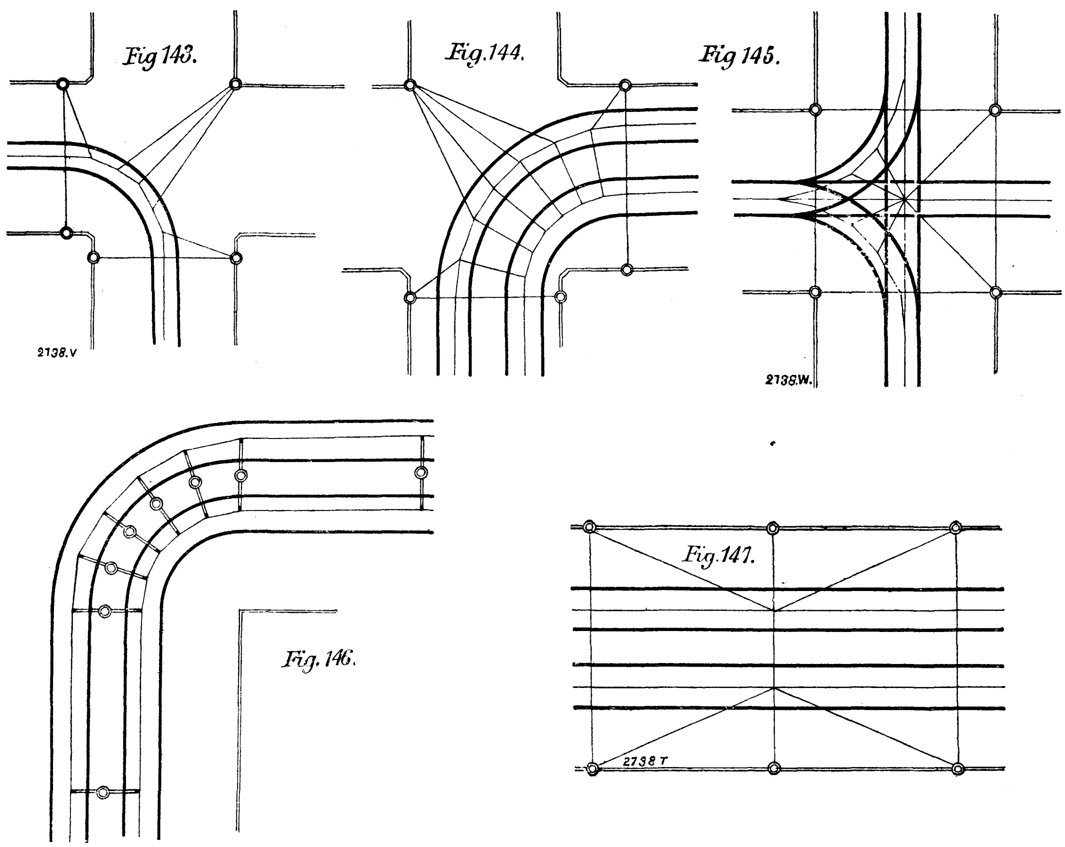


Fig. 142. Erecting Trolley Wires.

Fig. 142 shows an erection gang and tower wagons.

Where telephone or other wires cross the trolley wire, guard wires are sometimes hung over the trolley wire to prevent a short circuit, in case of one of these crossing wires breaking and falling. If there is a single line of track, two guard wires are employed, which are hung about 18 in. to 2 ft. above the trolley wire, one on each side. These must be



Diagrams of Trolley Wire Suspensions.

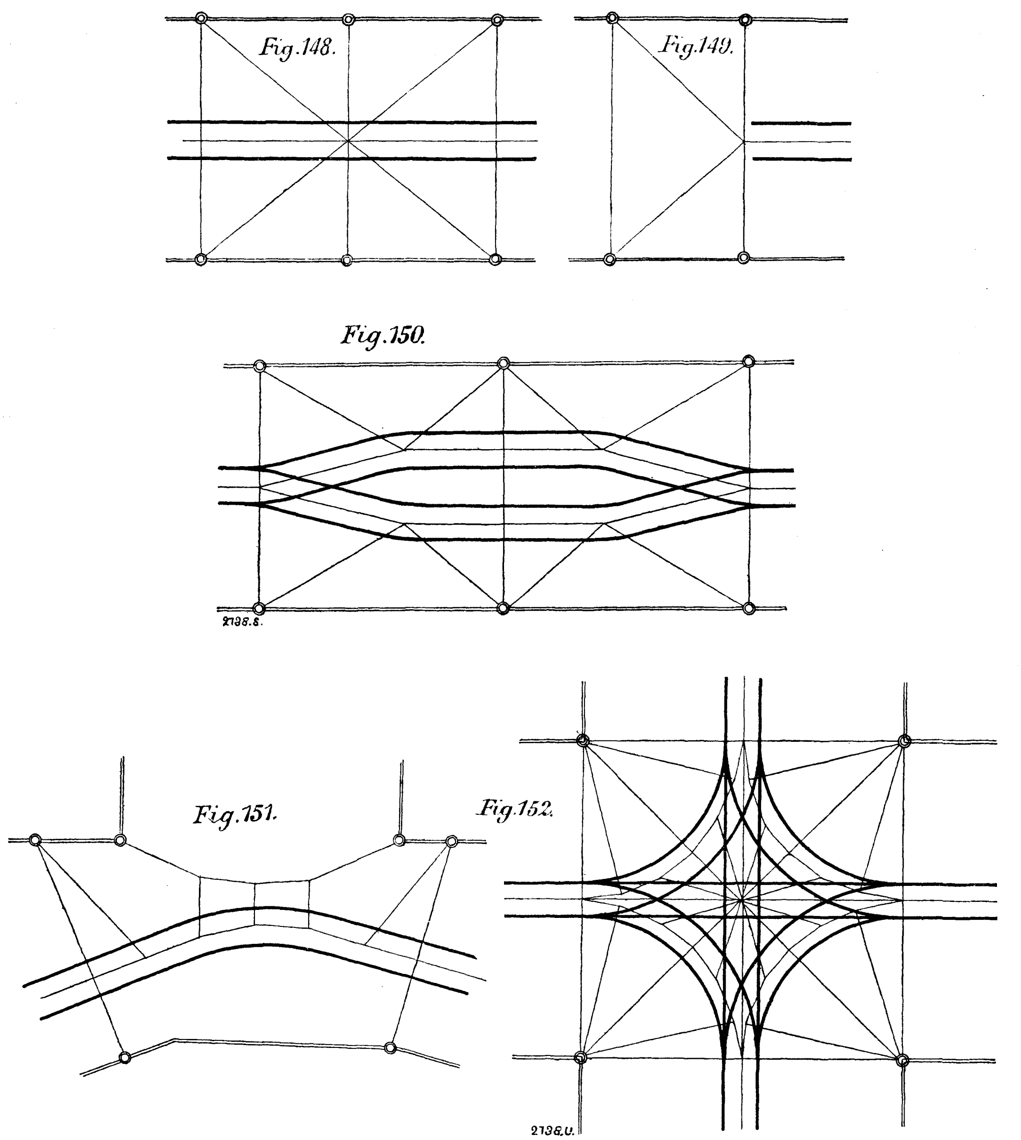
insulated from the poles. These guard wires are much more unsightly than the trolley wire, and, as often as not, cause as much trouble as falling telephone wires. If they are not very strong, the weight of a falling wire frequently causes them to break. To a great extent guard wires have been abandoned in America.

Figs. 143 to 152 are self-explanatory, and show various curve constructions, anchorages, and positions of insulators and poles.

The cost of the material and labour required in the installation of the

trolley wire (exclusive of poles and setting same) may be taken to be approximately as shown in Table XXXI.

The diagram, Fig. 153 gives an idea of how complicated the traffic is



DIAGRAMS OF TROLLEY WIRE SUSPENSIONS.

in some streets in Boston, and of relatively how few wires are necessary for suspending the wires over a double track with the most intricate and numerous curves and crossings. The diagram is taken from the system of street railways passing in front of the Old Colony Railroad station at

TABLE XXXI.—APPROXIMATE COST OF CONSTRUCTION, LABOUR, AND MATERIALS (EXCLUSIVE OF POLES AND SETTING).

	£
Per mile of single track :	
Cross suspension (by span wires attached to poles at either side of the roadway) ...	250
Bracket arm suspension (by brackets fixed to a single line of poles along one side of the track only) ...	300
Additional cost for each 200 ft. turnout ...	25
,, ,, ordinary curve ...	30
,, ,, overhead feeder connection ...	2
,, ,, anchorage ...	10
Per mile of double track :	
Cross suspension ...	440
Suspension from double-bracket arm poles placed between the tracks ...	430

TABLE XXXII.—APPROXIMATE COST OF POLES AND SETTING SAME PER MILE OF TRACK.

	£		£
Cross suspension, iron poles ...	400	to	1,200
,, ,, wooden poles ...	100	,,	300
Bracket arm suspension, iron poles ...	250	,,	850
,, ,, wooden poles ...	90	,,	600

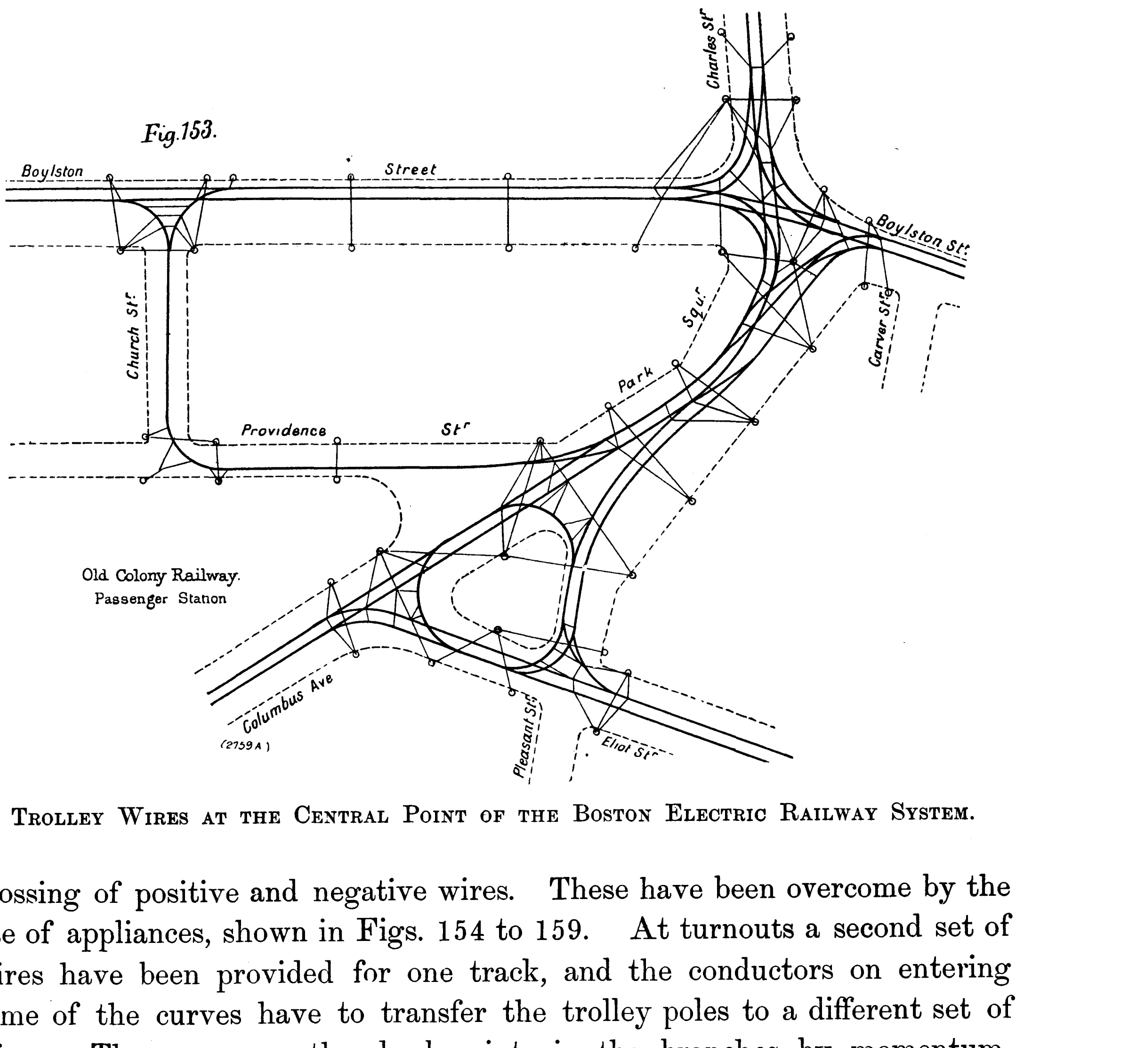
TABLE XXXIII.—SHOWING VARIOUS TOOLS USED ON LINE CONSTRUCTION.

Long-handled shovels.
,, spoons.
Digging and tamping bars.
Poles for erecting poles, if for wooden ones, with spike at one end, if for iron, with a U at one end.
Hammer, hatchet, chisel, saw.
Monkey wrench.
12 in. gas pliers and side cutting pliers.
Carpenter's level.
Cold chisel.
Ladder.
Block and fall and hand line.
Soldering kit, consisting of furnace, pot, ladle, and special soldering irons.
Bolt cutter, turnbuckle or wire-stretching machine.
" Come-along " and trolley wire clamps.
Vices.
Flat bastard files.
Round files.
Screwdrivers.
Wooden mallet.
Steel tape measure.
Acid jug and charcoal.
Solder (about 6 lb. per mile of single track).

Boston, Mass., a very busy centre for the electric cars coming and going in all directions.

The double trolley, or all metallic system, has been adopted at Cincinnati. The telephone company were so powerful, that when the railway company applied for a franchise, the latter was forced to adopt this system to avoid as far as possible any interference with the telephone circuits. The principal difficulties encountered were in preventing short circuits at the

Fig. 153.



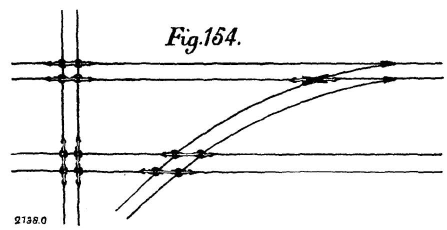
TROLLEY WIRES AT THE CENTRAL POINT OF THE BOSTON ELECTRIC RAILWAY SYSTEM.

crossing of positive and negative wires. These have been overcome by the use of appliances, shown in Figs. 154 to 159. At turnouts a second set of wires have been provided for one track, and the conductors on entering some of the curves have to transfer the trolley poles to a different set of wires. The cars pass the dead points in the branches by momentum, the current being carried past these points by insulated cables above the frogs. This system works satisfactorily, but it necessitates an enormous and most objectionable increase in the number of aerial wires. It also seems impossible to insulate the line properly. If one of the trolleys be taken off

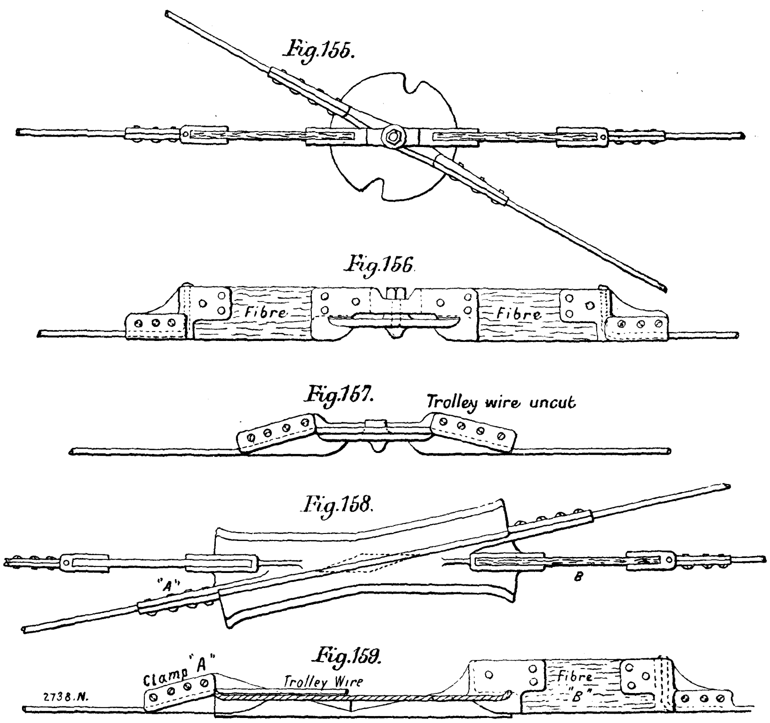
the line and connected to the rails, sufficient current will flow to light up all the lamps in the car, although not sufficient to move the car.

Figs. 160 and 161 are views of the double trolley system as carried out in Cincinnati.

A word may be said in connection with the appearance of overhead



Double Trolley Wire Points and Crossings.



Appliances for Trolley Wire Crossings.

conductors. Undoubtedly some aerial lines have been put up with an utter disregard of appearances, and inexperienced or careless constructors have erected webs of trolley, strain and feeder wires which were most obnoxious. This is especially true of many hastily-built American lines, pushed through at high pressure, and at the smallest possible expenditure. Now that the

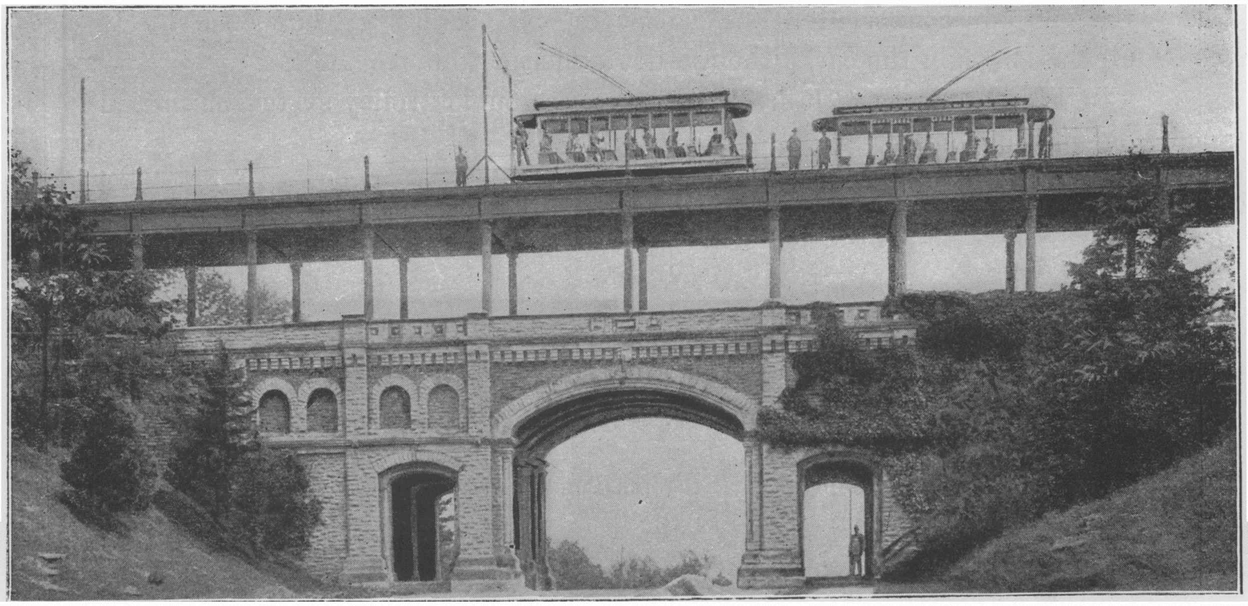


FIG. 160.

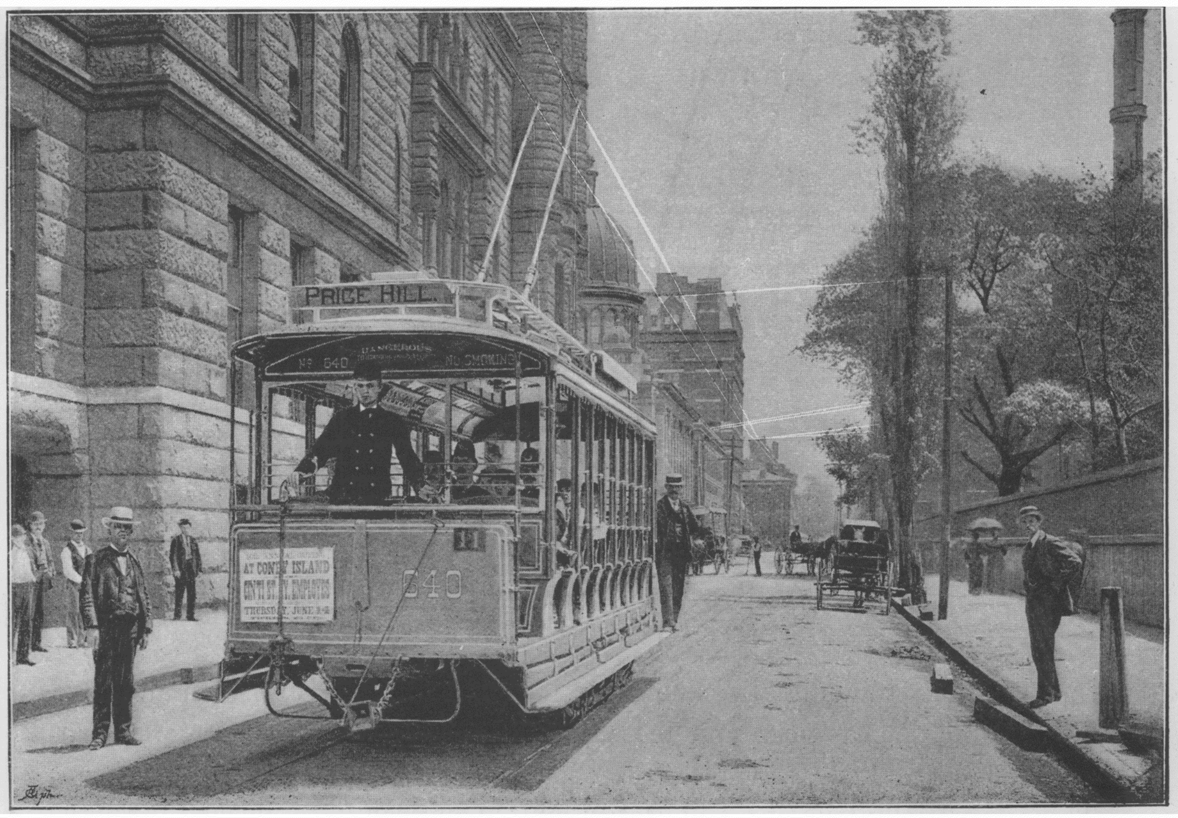


FIG. 161. DOUBLE TROLLEY SYSTEM IN CINCINNATI.

first rush is over, and the tramway operator, the manufacturer, and the contractor have had time to take breath, the weight of public and Press criticism has had its effect, and no pains is spared to perfect the entire plant and apparatus. A carefully designed and erected line, with subsurface feeders, handsome poles, &c., has but few objectionable features; and in the great majority of cases public convenience is so largely benefited by the numerous advantages that closely follow upon the introduction of improved and more rapid transit facilities, that opposition to the extension of a trolley line is now almost unknown in the United States.

The Bristol, Dublin, Guernsey, and country lines have conclusively demonstrated that the overhead trolley-wire, properly erected, is not obnoxious to the English eye. The work there done is equal to the best American examples, and greatly superior to the aerial constructions which have been put up in Continental cities. It may be confidently said that English corporations have ceased to view the trolley-wire with disfavour, and that in the near future we will cease to hear that outcry against overhead wires which has proved so great a bar to electric traction in Great Britain.

The recent reports of deputations from Glasgow, Leeds, Dublin, etc., which have visited the great Continental and American electric railways, are conclusively in favour of the trolley-wire as against all other systems.

CHAPTER VIII.

MOTORS.

AS it is proposed to describe only the predominant forms of apparatus, and the most recent practice, and as the scope of this work is neither historical nor mathematical, we will not touch upon obsolete types, or enter into long calculations for designing motors. Existing text-books have fully treated these subjects.

The motors used in the early days were all of the double-reduction type of gearing, and the waste of power in a double transformation of the high armature speed to that of the car axles was very great, an efficiency of 60 per cent being rarely obtained.

At the present time, good design, workmanship and materials have so changed the situation for the better that 80 per cent. efficiency is usually attained under most conditions, that efficiency remaining constant with widely varying loads.

When the application of electricity as a means for propelling street cars was first practically undertaken, the effort of the designers really was to apply the existing stationary motor to existing running gear. Connection between motor and axle was maintained by means of belts, sprocket chains, friction clutches, and other mechanical devices, all of which, with few exceptions, have now been abandoned, on account of the great expense of their maintenance and their low efficiency. Double reduction spur-gearing was first introduced on the experimental line at Woonsocket, R.I., jointly equipped in 1886 by the Thomson-Houston and Bentley-Knight Companies, and the advantage of a specially-constructed and self-contained motor truck were there demonstrated.

The high speed and comparatively cumbersome construction of motors at that time necessitated a double reduction in gear between armature and axle of about 9 to 1. This required an armature speed of about 1,500 revolutions per minute, with a car speed of about 15 miles per hour.

The later types of double reduction motors, of which a great many have been employed both in the United States and Europe, have given

excellent service; but as time passed and competing companies struggled for favour in the traction field, more advanced designs were developed.

The electric motor having demonstrated its ability to do the required work, the next problem was to so improve it as to make operating expenses as small as possible. This was practically effected by improving the design of the double reduction motor, and to a much greater extent by the introduction of single reduction gearing. Single reduction having proved successful, there was a rush for still further improvement in the design, and motors mounted directly upon the axle to be driven, and free of all gearing, were developed. These, however, have never gone into practical use for street car service, on account of their increased weight, and rapid deterioration owing to having no spring support, and receiving consequently all the shocks due to the comparatively rough track always encountered on street railways. This increase of weight and deterioration, and consequent increase of original cost and maintenance, has prevented their competing on even terms with improved single-reduction street railway motors.

The perfection of the design of single-reduction motors marks a distinct epoch in railway motor construction. The practical experience of several years has proved them reliable and efficient, and they have fairly fulfilled the essential requirements of a street railway motor, which are:

1. The motor must be as light in weight as possible, having due regard to thoroughly strong and simple mechanical and electrical construction.

2. It must be completely closed in and protected from dirt, water, &c.

3. The capacity of the motor must be ample, and it should be able to run continuously for at least two hours at its rated capacity without undue heating, say beyond 50 deg. Cent. It should be capable of developing at least 50 per cent. more than its rated capacity, without injurious sparking or other damage, and the starting torque must be very great.

4. All the external and internal parts of the motor must be thoroughly accessible, and easily taken apart.

That motor is the best which costs least to operate (cost of operation including fixed charges as well as running expenses).

The relation between weight of motor and expense is very forcibly shown by the maintenance of way on various roads at present operated.

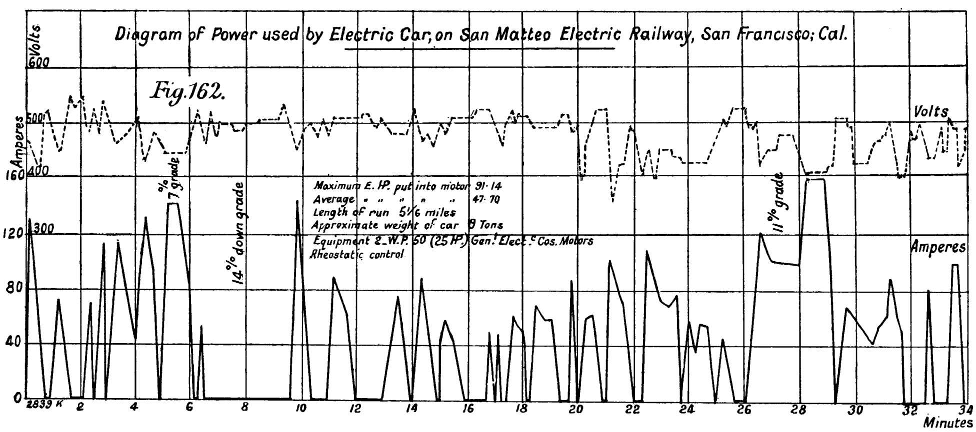
A motor entirely protected from dirt, water, &c., needs far less repairs, and so decreases the cost of operation.

It is obvious that if a motor does not keep within a certain limit of heating and sparking, renewals of parts will become numerous and costly.

Non-accessibility of parts means higher rates for maintenance and labour.

More than one reduction in gearing between axle and armature means too high speed of the armature, and consequently too great wear in the teeth. Any decrease in number of parts and bearings decreases maintenance. Large teeth must be used, and the gears must be run in grease.

To appreciate the conditions which have made the designing of efficient street railway motors a far from easy task, let us examine the sort of work which they have to do. The diagram (Fig. 162), for which we are indebted



Power Diagram from Electric Railway.

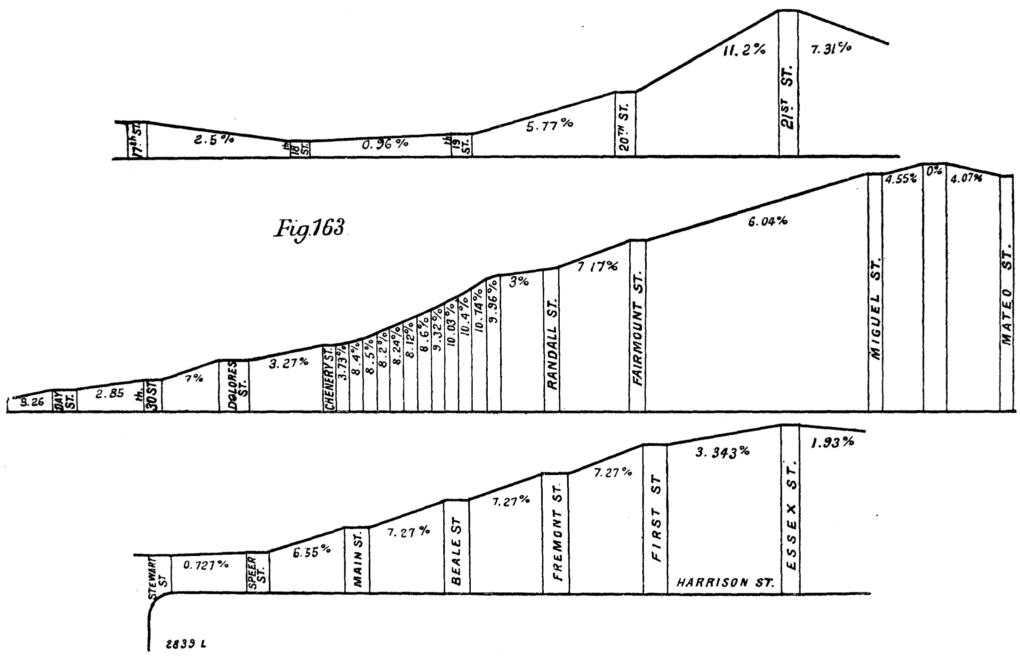
to the courtesy of Mr. A. H. Babcock, chief engineer of the General Electric Company at San Francisco, represents the plotted results obtained from ammeter and voltmeter readings taken every 10 seconds on one of the steepest grade electric roads in America—the San Matteo Electric Railway at San Francisco. Fig. 163 gives profiles of the steepest parts of this road.

As will be at once noticed, the variations of load on the motors are very great, the average load for the run being 47.7 electrical horse-power, whilst the maximum electrical horse-power expended is 91.14. The length of the run is $5\frac{1}{6}$ miles under the ordinary working conditions. The equipment of the car tested consisted of two " W. P. 50 " single-reduction motors by the General Electric Company of America (Thomson-Houston system), rated at 25 horse-power each. From this it follows that a street railway motor, while being as light as possible, must have an efficiency which

remains near the maximum over a very large variation of output, and must be able to stand very heavy overloading for a short time.

Mr. H. F. Parshall, in a paper read before the American Institution of Electrical Engineers, brings this out clearly.

He states that the average horse-power exerted by a street-car motor at the car wheel probably does not exceed 20 per cent. of the maximum power it is expected to exert in starting the car under the various conditions encountered. To get the best efficiency out of such a motor, it is necessary to have its point of highest possible efficiency at that horse-power



Profile of the San Matteo Electric Railway.

at which the greatest amount of work is to be done; it is not so much a question of reducing the resistance of the armature and magnets, as it is of minimising the constant loss through hysteresis, eddy currents, and friction. To minimise these losses, and at the same time obtain the required torque, it became necessary to put the maximum number of turns on the armature compatible with good running and absence of heating and sparking. The brushes on a railway motor must run without appreciable sparking at all loads, and without shifting. To insure this it has been found necessary to use very heavy magnetic inductions, such as 100,000 C.G.S. lines of force per square inch in the yoke, 60,000 C.G.S. lines of force in the air space, and 80,000 C.G.S. lines of force in the armature core.

Carbon brushes are universally used with the best results, the commutators always keeping in excellent condition. A very vexed point, and one which for a very long time remained undecided, was whether a gramme ring or drum armature was the best suited for street railway motors. It seems now to be nearly universally admitted that a drum, wound with the "Eickemeyer" type of winding, which prevents coils with different potential crossing each other, is the most advantageous. The coils composing the armature winding are all made separately on forms (Fig. 164 shows such a coil and armature), and then laid in wedge-shaped

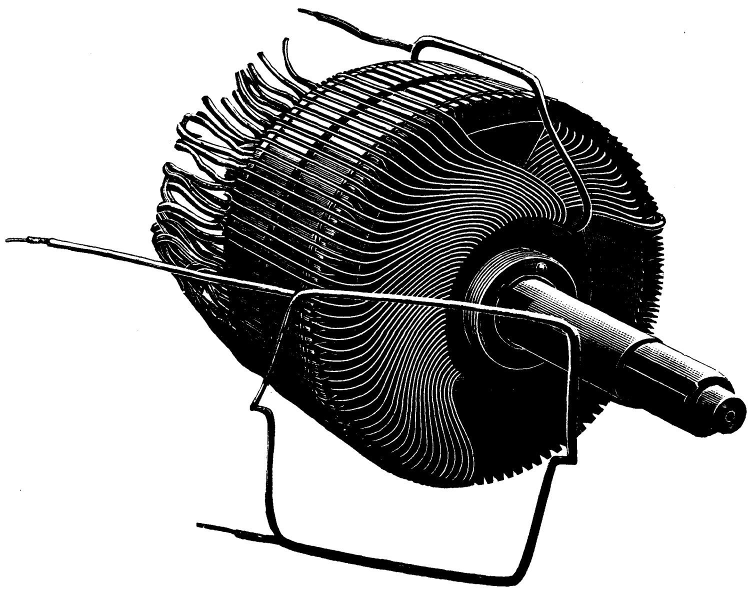


FIG. 164. "EICKEMEYER" WINDING FOR MOTOR ARMATURE.

grooves cut in the face of the armature core, in which they are kept in place by wooden wedges and steel binding wires. The armature core of the motor is composed of laminated soft iron discs which have been heated, so that their surface is covered with a black oxide which suffices as insulation to prevent the formation of Foucault currents, the use of paper between each disc having been discarded. The slots in which the windings are laid are punched out with the individual discs, and after the discs have been assembled on the shaft and the core is formed, they are filed out by machinery so as to present perfectly smooth surfaces. The insulation used should be as nearly non-inflammable as possible, and the armature coils, besides being insulated by their cotton covering and taping, are generally

separated from the iron of the armature by thin sheets of mica. When an armature is wound, both its sides are generally protected by sheet-iron guards, and a waterproof and fire-resisting canvas, which is wrapped and securely fastened round the whole armature. For this purpose, the American companies almost universally use the "P. and B." motor cloth.

Great care must be taken in the construction of the motor commutators. Fig. 165 shows a section through a type of commutator much used in America, and which has given very good results; it is self-explanatory. Owing to the almost universal use of slow-speed motors, most of the standard forms have four or more poles, the armature

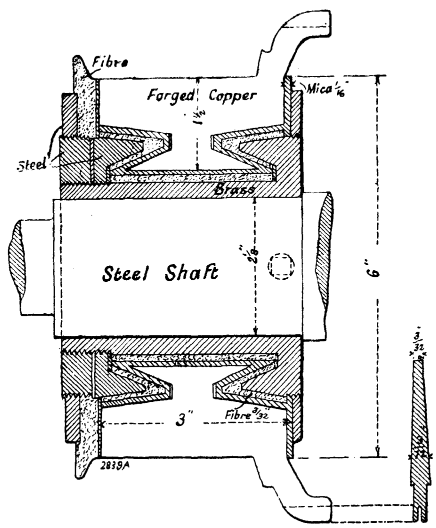


Fig. 165. Section through Motor Commutator.

winding being cross connected so as to require the use of only two sets of brushes.

It is now a nearly universal practice to make the yoke and framework of railway motors of mild cast steel and entirely boxed in, so that neither water nor dust can reach the armature, brushes, or gearing, and the latter runs in an oil bath.

Table XXXIV, compiled from data furnished by the Walker Manufacturing Company, gives the average horizontal effort in pounds exerted by two single-reduction motor equipments of 25 and 30 horse-power corresponding to various speeds. Table XXXV. gives the current consumption for the same equipments corresponding to the horizontal efforts given in the preceding Table. The total car equipment in the tests made in

TABLE XXXIV.—AXLE SPEED PER CAR WITH DOUBLE-MOTOR EQUIPMENT. REVOLUTIONS PER MINUTE.

Diameter of Wheels.	Average of several Types of 25 H.-P. Motors. Horizontal Effort, Pounds.									
	100	200	400	600	800	1,000	1,200	1,400		
in.										
30	308	253	195	170	153	141	131	122		
33	300	248	189	165	149	136	126	119		
	Average of several Types of 30 H.-P. Motors. Horizontal Effort, Pounds.									
	100	250	500	750	1,000	1,250	1,500	2,000	2,500	3,000
30	282	260	202	173	153	139	130	117	107	100
33	272	252	194	166	148	134	122	113	103	25

TABLE XXXV.—CURRENT CONSUMPTION PER CAR-AMPERES.

Diameter of Wheels.	Two 25 Horse-Power S. R. G. Motors. Horizontal Effort, Pounds.									
	100	200	400	600	800	1,000	1,200	1,400		
in.	amp.	amp.	amp.	amp.	amp.	amp.	amp.	amp.		
30	25.8	32.8	44.6	54.6	63.8	72.6	82.6	92.0		
33	26.6	34.0	47.0	57.6	67.4	77.6	88.4	98.2		
	Two 30 Horse-Power S. R. G. Motors.									
	100	250	500	750	1,000	1,250	1,500	2,000	2,500	3,000
	amp.	amp.	amp.	amp.	amp.	amp.	amp.	amp.	amp.	amp.
30	28.6	38.8	51.4	63.0	73.2	84.2	93.4	111.8	130.0	147.6
33	29.4	40.0	54.0	65.8	77.0	88.8	98.8	119.2	138.8	158.0

TABLE XXXVI.—ELECTRIC POWER CONSUMED BY VARIOUS CARS.

Style of Equipment.	Condition of Track.	Average Time between Stops, in Minutes.	Weight of Motor Car, in Tons.	Board of Trade Units per Car-Mile.	Average Speed.
Two Westinghouse motors on car, one trailer	good	0.43	$7\frac{1}{2}$	1.001	8.6
Two Westinghouse motors on car, two trailers	dry	0.40	$7\frac{1}{2}$	1.497	6.4
Sperry bevel gear, one motor, no trailer	,,	0.60	6	1.160	10.0
One Westinghouse motor, no trailer...	greasy	0.30	$6\frac{1}{2}$	1.202	7.8
Two Westinghouse motors, no trailer...	,,	0.30	$7\frac{1}{2}$	1.233	12.0
Two General Electric Company's motors, no trailer	dry	0.31	$7\frac{1}{2}$	1.019	1.00

compiling these Tables weighed $7\frac{1}{2}$ tons, and was mounted on a four-wheeled truck of 6 feet wheel base. The horizontal effort and corresponding current are functions of the speed. With the aid of these data it is easy to work out what would be the current consumption at a given speed on a given road. Table XXXVI., also from actual tests, gives the average power consumed by motors under various conditions.

We will now describe some of the most important and recent types of motors.

Edison Motor.—A motor which may be said to have been one of

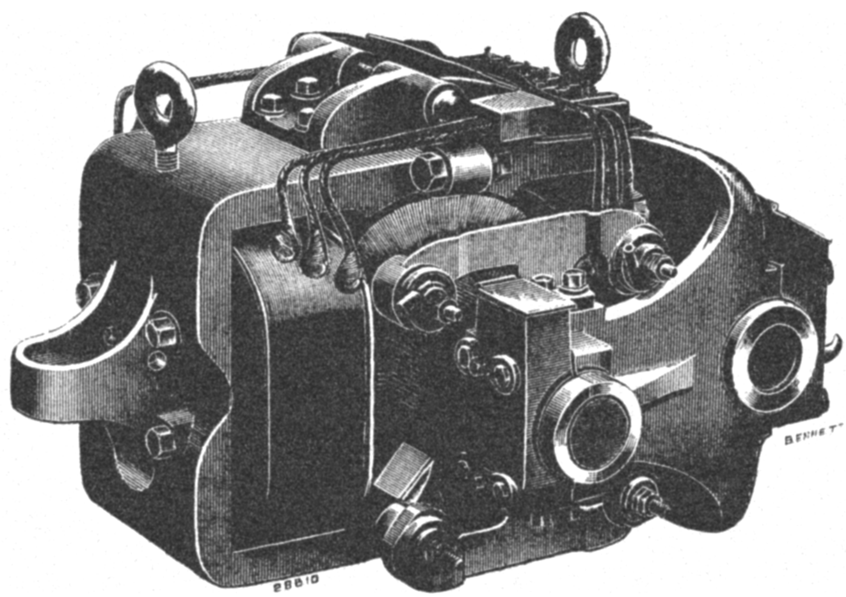


Fig. 166. Edison Single Reduction Motor.

the best of its day was the Edison single-reduction motor built by the Edison General Company in 1891 (Fig. 166) This motor is running very successfully on many American lines at the present day, and is still manufactured by the General Electric Company of America. In many of its electrical details it resembles very much the latest type of street railway motor. It is a four-pole motor; two poles only are wound with coils, the two in the vertical plane being consequent poles of opposite polarity. The whole frame is of mild steel, cast in halves and bolted together. The armature is a Gramme ring with "Pacinotti" teeth. In the interior of the armature core there are four grooves 90 deg. apart, into which aluminium bronze spiders are forced by hydraulic pressure;

two spiders are employed for each core, bolted together in the centre. The winding consists of 140 sections put on in one continuous length of wire. A german-silver tap wire connects each section to the corresponding commutator sections. The armature winding is not cross-connected, and four sets of brushes have to be used.

THE "G. E. 800" MOTOR is manufactured by the General Electric

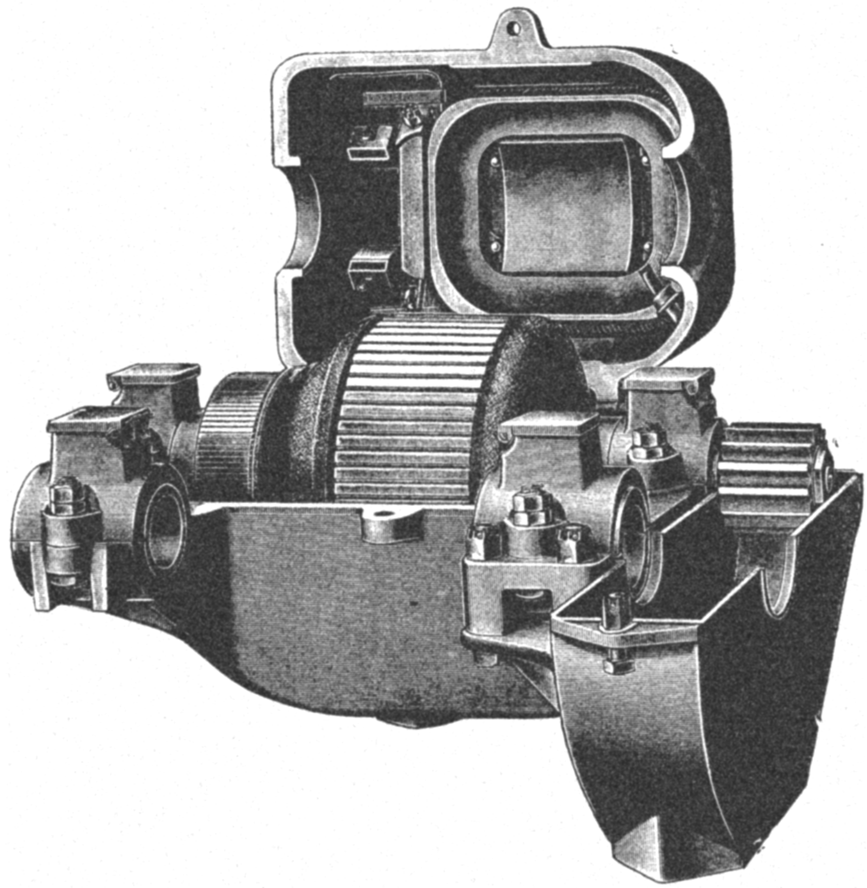


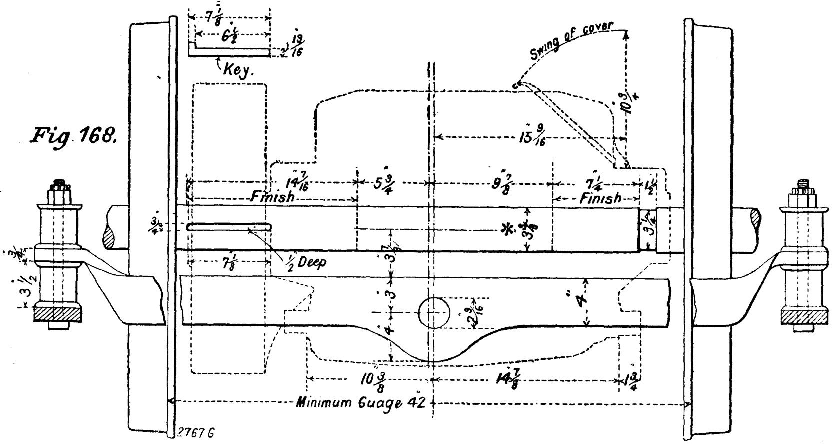
FIG. 167. "G. E. 800" MOTOR.

Company of America, and the several "Thomson-Houston" companies controlling the same patents in Europe (see Figs. 167 to 173.)

The trade name under which the motor is known indicates its ability to exert a horizontal effort of 800 lb. through a 33-in. wheel continuously in ordinary street-railway service. This rating is more accurate than that customarily employed; adopting the usual mode of rating in horse-power, it is a 25 horse-power motor. It is a four-pole motor of new design. Its

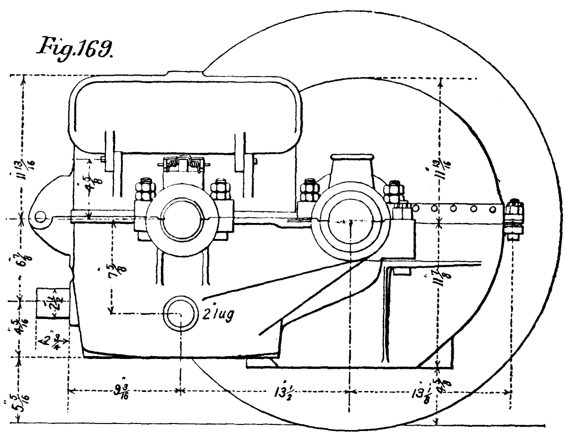
principal characteristic, and the one that recommends it especially for street-railway work, is that it is claimed to be the lightest motor for a given output. Reduction of weight has been carefully studied, with a view of meeting the demands of the continually growing street-railway business. Preservation of the permanent way is of great importance to every electrical

Fig. 168.



" G. E. 800 " MOTOR. REAR ELEVATION. " NOSE " SUSPENSION.

Fig. 169.



" G. E. 800 " MOTOR. ELEVATION, COMMUTATOR SIDE. " NOSE " SUSPENSION.

street-railway company, and this has created a demand for a motor light enough to reduce the wear and tear of track to a minimum. This motor is no less than 660 lb. lighter than the old single reduction (" S. R. G.") 15 horse-power motor, and some 200 lb. or 300 lb. lighter than the waterproof (" W. P.") 15 horse-power motor formerly manufactured by the same company (see Table XXXVII.)

TABLE XXXVII.—WEIGHT OF MOTORS MADE BY THE GENERAL ELECTRIC COMPANY, LIMITED.

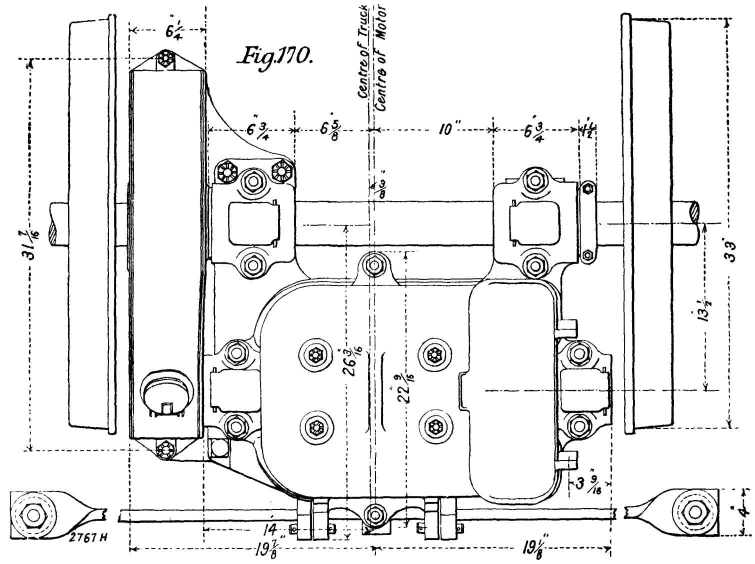
Name of Motor.	Rated Power.	Weight.	Weight on Axle.
	h.-p.	lb.	lb.
Old type Thomson-Houston double reduction	10	1,472	
Ditto ditto ditto	15	2,096	1,222
Ditto ditto ditto	20	2,818	
Single-reduction Edison	20	1,600	
Ditto ditto	30	2,270	
Single-reduction Thomson-Houston Waterproof (W.P. 30)	15	1,735	937
Ditto ditto ditto (W.P. 50)	25	2,395	1,307
General electric single reduction ... ...(G.E. 800)	25	1,455	715

On the single-reduction motors the pinions have 14 teeth and $4\frac{5}{8}$ in. pitch diameter; the gears have 67 teeth and $22\frac{1}{3}$ in. pitch diameter, and the speed reduction is 4.78.

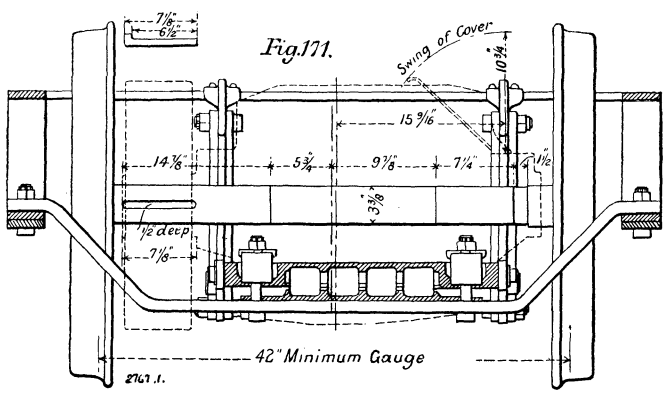
Working parts are more easily accessible than in any of the former types. The aperture necessary for the purpose of inspection, cleaning, &c., is so designed that, when closed, those parts which could be damaged by water—the brush-holders, commutator, armature, and field spools—are so entirely enclosed in a water-tight box that it is said that the entire motor could be immersed in water, and still operate under normal conditions. This advantage is one which can be easily appreciated by those engaged in the practical operation of electric railways, since it renders the motor of equal value in either summer or winter service, in either bad or good weather.

This closing of the motor so as to make it water- and dust-proof has been rendered possible by its modern design and the liberal use of copper and the best grade of steel in its construction, whereby the heat generated in the motor has been materially reduced. The motor, closed up as it is, runs quite cool. It can be taken apart with the utmost facility. The top frame is hinged on to the lower frame, and with its proper parts weighs 350 lb. On the removal of two bolts this frame can be thrown back completely out of the way of the armature (see Fig. 167), or by the removal of the hinge pins the top frame can be lifted into the car. By moving the noseplate forward, the motor can be swung on the ring axle as a hinge, so as to be accessible from the pit, the top field then being swung on its hinges still lower into the pit, in which position the armature and the two field spools can be easily removed. By the removal of the top of the gear case and two axle caps, the motor can be lowered as a whole into the pit. The armature is short, and can be lifted through an ordinary trap

door. It will be seen that the motor can be handled either from inside the car or from without with almost equal facility. On opening the lid over the commutator easy access is had to the whole width of the commutators and brush-holders, the latter being of a very simple con-



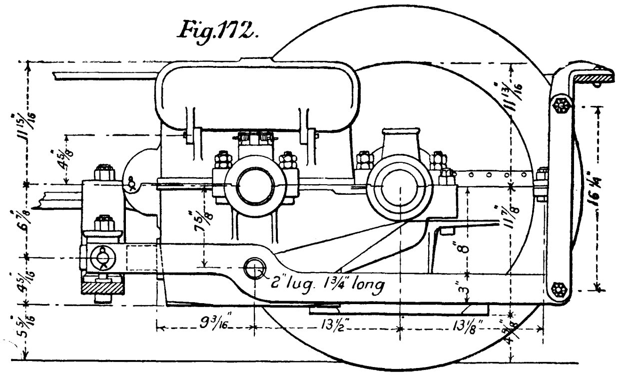
"G. E. 800" MOTOR. PLAN. "NOSE" SUSPENSION.



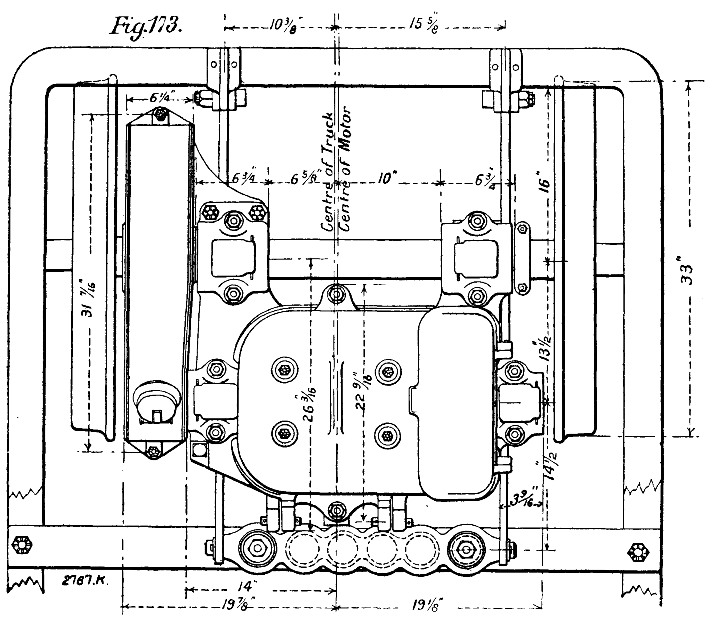
"G E. 800" MOTOR. REAR ELEVATION. "SIDE-BAR" SUSPENSION.

struction, and easily operated with one hand. There is plenty of space to permit of the pit of the motor being reached. The bottom of the armature is 2 in. above the top of the motor, so that it is not liable to be injured by articles falling inside of the motor frame. The armature is made both in the Gramme ring and in the drum form. A thorough trial has

demonstrated that the drum winding of this motor can be relied upon, and that it is free from the danger of burning out at the ends. The Gramme armature and drum armature are interchangeable. The resistance of the standard type of armature when cold is 0.38 ohm, and 0.5 ohm when hot.



"G. E. 800" MOTOR. ELEVATION COMMUTATOR SIDE. "SIDE-BAR" SUSPENSION.



"G. E. 800" MOTOR. PLAN. "SIDE-BAR" SUSPENSION.

Connections to the commutator are made by short leads of flexible cable joined to the bars by solid cups ; this is done to absorb the vibrations and prevent rupture of the wires at this point. Two field coils are employed although it is a four-pole motor, as two are consequent poles. These coils are wound on forms and wrapped with waterproof and fire-

resisting material. To reduce the danger of grounding, the field spools are connected on the ground side of the circuit. The resistance of the field when hot is 0.8 ohm.

All the bearings are lined with babbit. Under each of the armature bearings is a canal leading outside the frame, which carries off the overflow of grease. In addition to the grease cups, the axle bearings have oil wells underneath. If not provided with oil, it has been found that even although running perfectly cool, the bearings cut.

There are two ways in which the motor is hung from the truck: one called " nose suspension," and the other known as " side-bar " suspension. In the former method one end of the axle rests on the motor through its bearings, the other being hung by a crossbar and springs from the truck

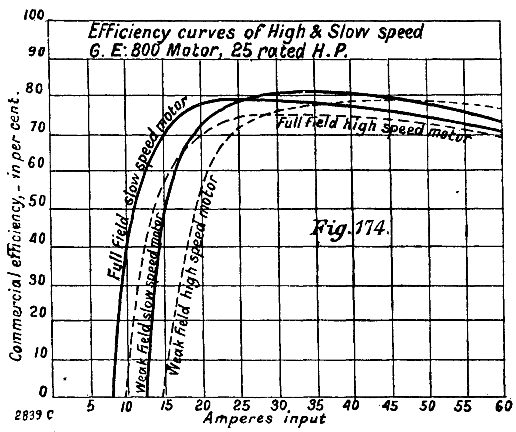


Fig. 174.

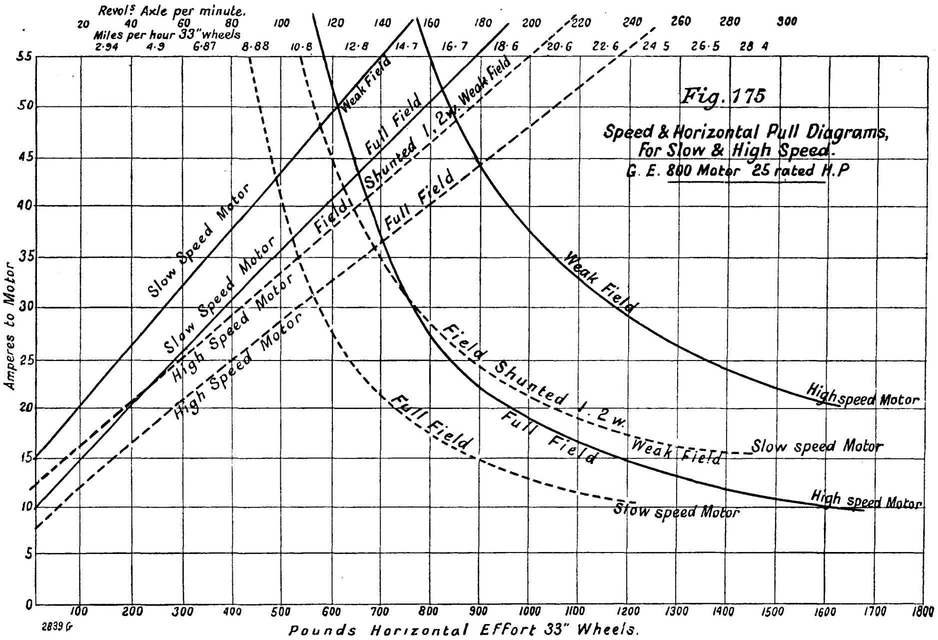
(Figs. 168 to 170). An advantage claimed is that the gear wears more evenly. The latter, although the older, seems still the method most adopted.

In the "side-bar" suspension the weight is nearly wholly taken oft the axles (Figs 171 to 173). A side frame resting entirely on springs, carries the motor by two lugs, one on either side, which are so placed that the motor is suspended from its centre of gravity. This, although apparently a very good plan, has not proved the success anticipated, and the first, or " nose suspension," is still one much in use. The motors are provided with lugs, so that either mode of suspension can be used.

Diagram Fig. 174 is very interesting and instructive. It represents the efficiency curves of two of the most recent types of " G.E. 800 " motor constructed for American country and city (high and low speed) service. Fig. 175 shows the corresponding horizontal pull in pounds on a 33-in.

wheel and speed in revolutions per minute. The curves are taken for the full field strength, and for two-thirds of the full field strength, attained by the use of a shunt of 1.2 ohms in one case, and by putting the field windings in parallel in the other, the motor in either case being constructed for a line voltage of 500 volts.

We can draw some interesting conclusions from a study of the efficiency curves. We see that the average efficiency of the slower motor is greater than that of the faster one. In both cases the efficiency with full field is at first the highest. At a third of the maximum power for the slow-speed,



and at nearly half its maximum power for the high-speed motor, the weak field gives the highest efficiency.

It will also be observed that the slow-speed attains its full efficiency more rapidly than the high-speed motor. At the normal rate the current ranges from 20 to 40 in the slow-speed, and from 25 to 50 amperes in the high-speed motor, at which rate the efficiency is 80 per cent. This may be considered very high for traction work. In looking at the torque and speed curves, the difference of the two motors is very noticeable. In the slow-speed the torque curve increases much more rapidly than in the high-speed; or, in other words, a greater starting current is required in the use of the high-speed motor to effect the same pull in pounds on the periphery of the

wheel than with the slow-speed motor. There is also a great difference between the torque and speed curves for the full and weak field in the two motors. For instance, it would take to produce a pull of 700 lb. on the periphery of the wheel, respectively $36\frac{1}{2}$ and 46 amperes for the full field at speeds of 9 and 11 miles an hour, and 42 and 55 amperes for the weak field at speeds of 11 and 15 miles an hour correspondingly for the slow and high-

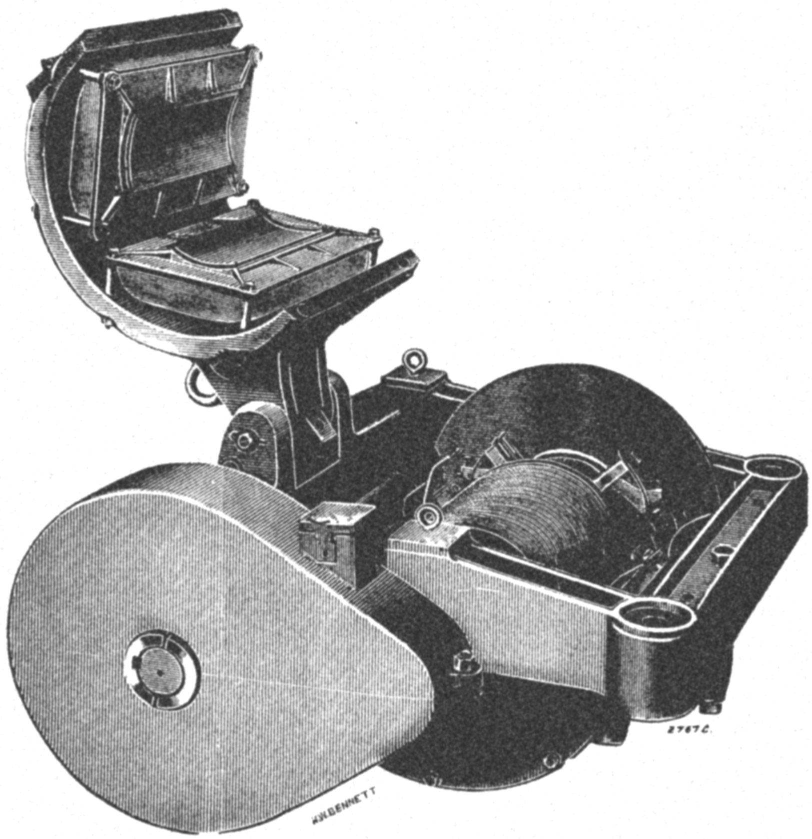


FIG. 176. WESTINGHOUSE STANDARD SINGLE REDUCTION MOTOR.

speed motors. But at a speed of 25 miles an hour we find 10 and 13 amperes for full field corresponding to a pull of 50 lb. in both cases, and for the weak field 16 and 26 amperes corresponding to a pull of 80 lb. and 190 lb. for the slow and high-speed motors respectively, this being distinctly in favour of the high-speed motor. From this we deduce that for the slower speeds to suit English lines, higher efficiencies still will be attained; and, therefore, operating expenses will be cheaper, as not only less energy will be consumed, but a greater efficiency will be attained. From the

torque and speed curves it is easy to calculate the effective horse-power at various current consumptions and speeds. To do this it suffices to find the horizontal effort in pounds on the wheel for a given speed or current for either the whole or the weakened field. Multiply this figure by the horizontal distance in feet covered by the car at that speed in one minute, and divide by 33,000. As we know the efficiency of the motor, we divide the figure thus found by the efficiency in hundredths, and we have thus the corresponding electrical horse-power taken off the line.

THE WESTINGHOUSE COMPANY'S SINGLE REDUCTION MOTOR (Figs. 176 and 177).—The Westinghouse Company's single reduction motor is made

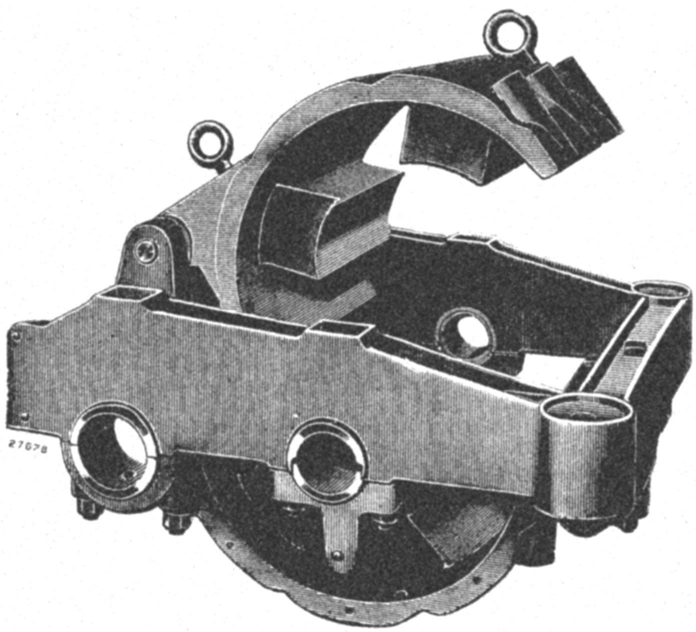


FIG. 177. FIELD MAGNETS, WESTINGHOUSE SINGLE REDUCTION MOTOR.

in standard sizes of 20, 25, 30, 40, and 50 horse-power. The armature, as in the case of the "G. E. 800," is drum-wound. The winding is laid in wedge-shaped slots, and is similar to the Eickemeyer type. The field consists of four poles, each with one field coil, projecting radially inwards from a circular yoke made in halves. On the side farthest from the car axle these halves hinge together. The brush-holders are two in number, the armature winding being cross-connected. They are 90 deg. apart, and on the top of the commutator.

The motor is entirely closed, and water- and dust-proof. A lid is arranged over the brushes so as to be able to inspect them easily.

The mode of suspension is a cross between the nose and side bar suspension (see Fig. 178). Two bars of rectangular section are bolted to the top of the motor; these are supported by coil springs on either side from crossbars of U-section hung from the frame of the truck.

The field opens downwards either with or without armature, as is desired.

The armature bushings are carried in pillow blocks, which are secured to both the upper and lower field. By removing the bolts holding the pillow to one or the other half of the field, only the field coils, or field coils and armature, can be removed or inspected.

The Walker Motor.—In common with all the other well-designed motors, this is completely water- and dust-proof. It has a four-pole

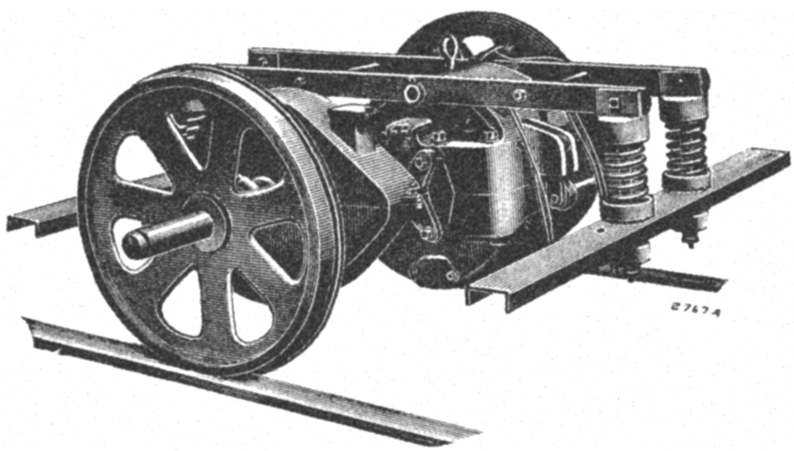


Fig. 178. Westinghouse Motor Suspension.

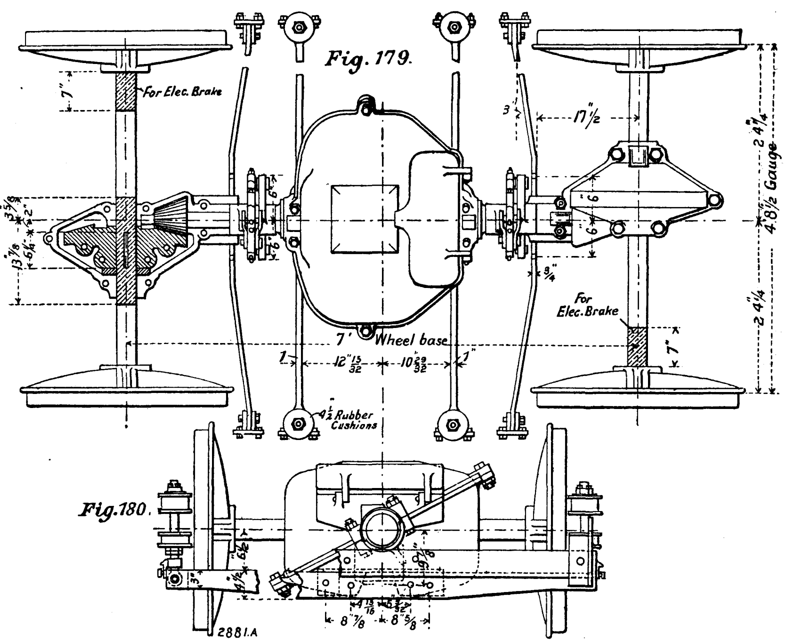
field, and resembles very much in outward appearance the Westinghouse construction.

The standard sizes are rated as 20, 25, and 30 horse-power, and for heavy work 40, 50, and 60 horse-power.

The method of suspension used is a particular feature of this system. The motor is hung by spiral springs from a U-frame resting at one end on the armature bearings, and on the other on the axle, the part of the motor furthest from the axle being supported by springs from a transversal bar as in the case of the "nose suspension" of the G. E. 800 motor. The lower half of the motor is hinged, and by loosening some bolts can be made to swing down. The armature, similar to that of the Westinghouse motor, can be left in or taken out at will. If no pit is available, the upper part of the motor can be opened from the top.

All the bearing caps come off from below, and all the bolts pass down from above. The main bolts are all of the same size and length, and interchangeable, and are not made to take the weight of the motor. The bearings are all entirely outside the motor casing or frame, and are lined with babbit. As in the case of all modern motors, the gears are enclosed in dust-proof boxes and run in an oil bath. The armature is of the toothed or Pacinotti drum type, with an Eickemeyer type of winding, cross-connected so as to require only two brushes.

THE SPERRY MOTOR (Figs. 179 and 180).—The peculiarity of this



PLAN AND ELEVATION OF SPERRY MOTOR.

motor lies more in the gearing than anything else. All those described so far are of the single-reduction type using spur and pinion gear.

In the present instance this has been abandoned, and bevelled gearing is used. The motor, hung by springs from the truck, drives both axles by means of a bevel gearing connected to each end of the armature shaft by spring clutches. High efficiency and low depreciation are claimed for this motor, and it has been used to a certain extent in America. As with all the motors already mentioned, it has four poles ; the armature is a gramme ring with Pacinotti teeth, and cross-connected inside, so that only two sets of brushes are required.

At one time the direct-coupled motor, either with the armature directly wound on the axles, or with the armature wound on a sleeve or quill slipped over the axle and connected to it by springs, or else driving the wheels by means of connecting-rods, seemed to be favourably considered; but experience has demonstrated that, with the possible exception of very heavy locomotives to work on railroads, for high speeds, and where the permanent way is supposed to be always in good repair, the only successful mode is to use single reduction gear of some kind.

There are a number of other makers of electric railway motors in the United States, but their systems are similar in most respects. In

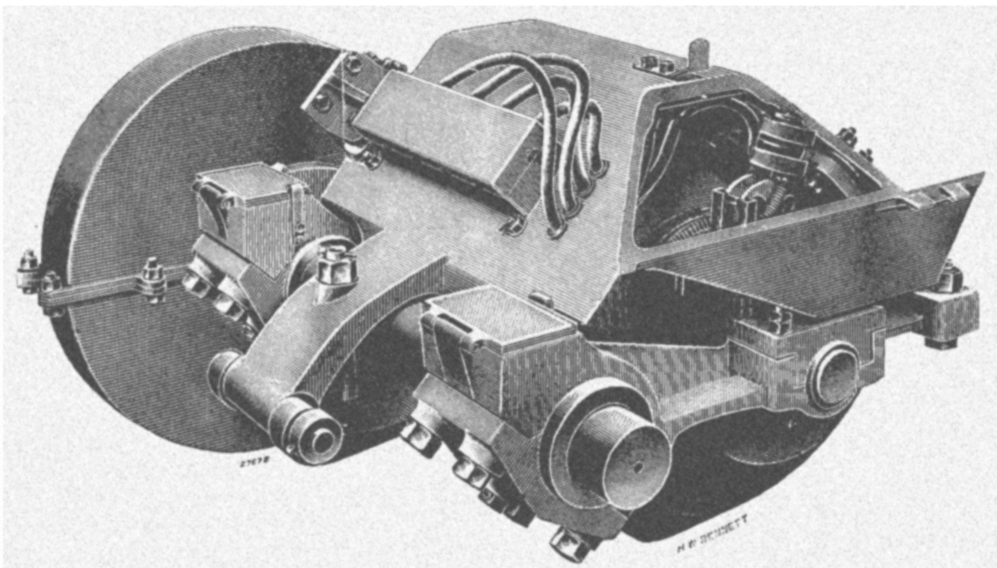


FIG. 181. "OERLIKON" MOTOR—CLOSED.

America the motor has gone through all the various stages of invention and improvement, and has come down to a standard type proved by experience to be the best suited for the class of work.

Motors are made by the thousand in the United States, and are turned out as neatly and well finished as steam locomotives are in this country; it may be fairly claimed that they have passed through the experimental period.

In Europe this stage is also rapidly being reached, as instanced by the motor (Figs. 181 and 182) constructed by the Oerlikon Maschinenfabrik, of Zurich, and which to all intents and purposes resembles the good American motor in all its details. Table XXXVIII. gives data of these Oerlikon motors.

TABLE XXXVIII.—MOTORS CONSTRUCTED BY THE OERLIKON COMPANY.

Drawbar Pull in Pounds at 9.4 Miles an Hour.	Rated Horse-Power.	Total Weight in Pounds, including Gearing.	Revolutions of Armature per Minute.	Speed Reduction.
440	10	1,764	450	1 : 5
661	15	2,050	450	1 : 5
882	20	2,424	400	1 : 4.2
1,322	30	—	350	1 : 4

Fig. 183 shows a truck with motors, constructed by Messrs. Schuckert and Company, of Nuremberg.

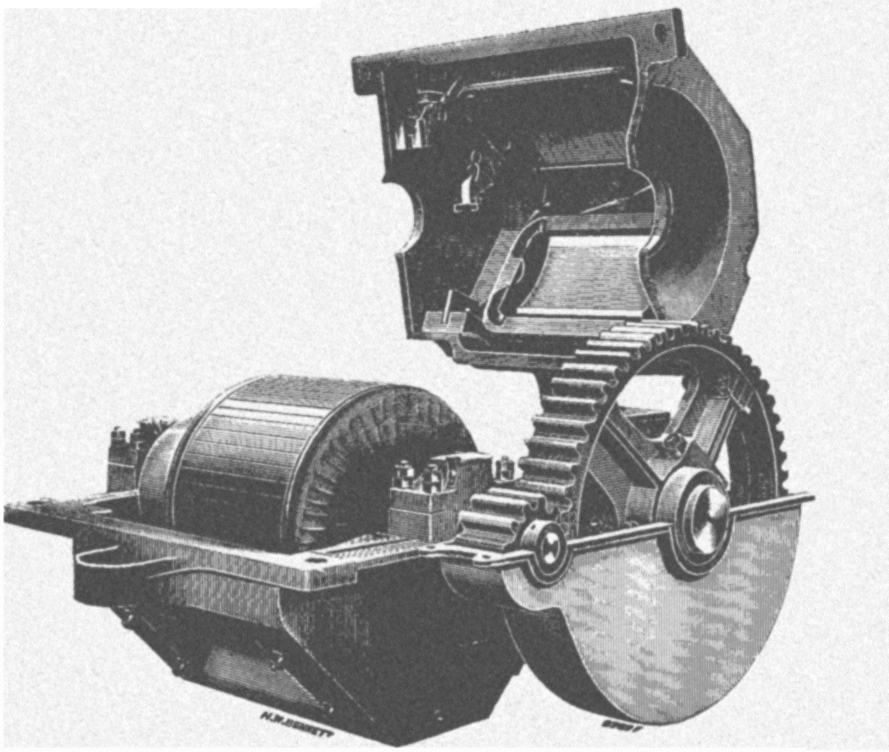


FIG. 182. "OERLIKON" MOTOR—OPEN.

The latest type of motor, as designed and used with the best results by the Allgemeine Elektricitäts Gesellschaft, of Berlin, is of the four-pole type; its armature makes 400 revolutions per minute, and it is rated at 25 horse-power. (Fig. 184).

Fig. 185 is the rear elevation of a railway motor, constructed by Messrs. Ganz and Company, of Budapest. This motor has four poles. The armature is a gramme ring, and its core is of the slotted or Pacinotti type. The field magnets and frame are of cast steel.

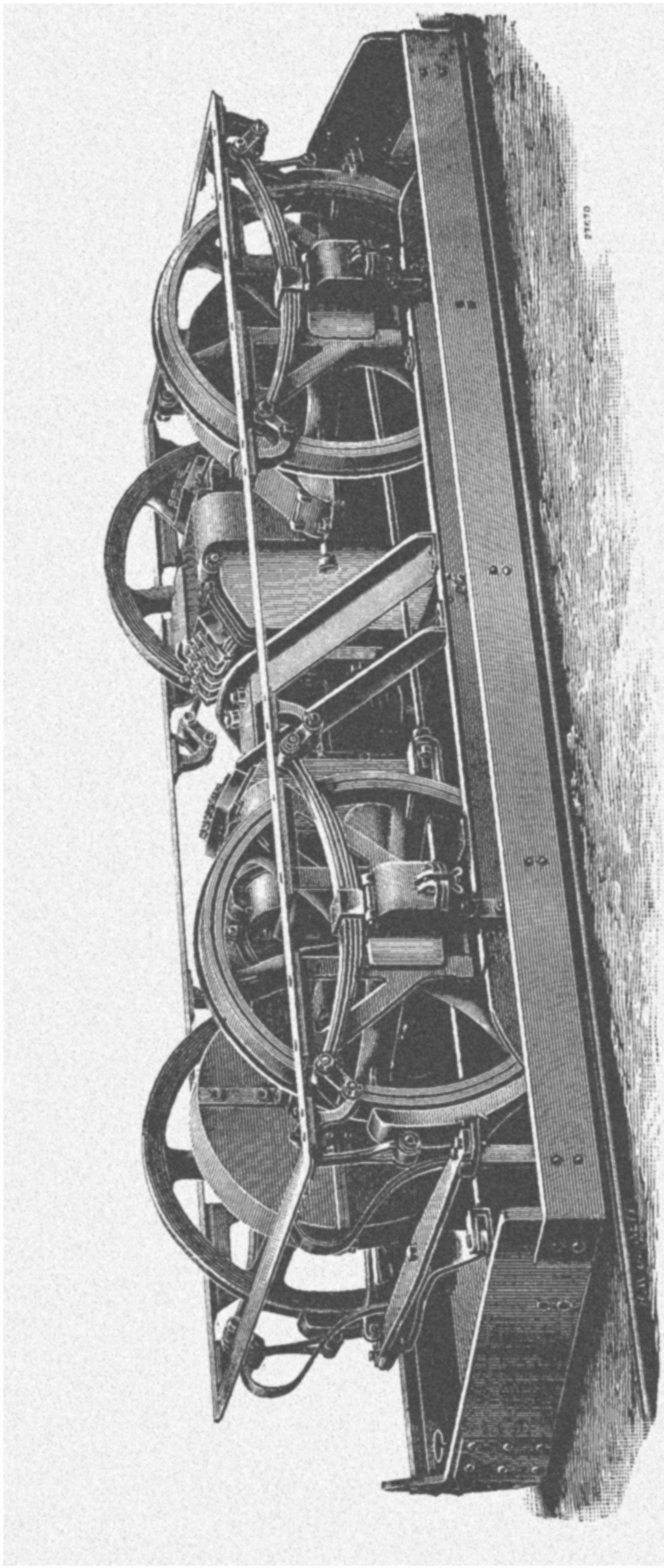


FIG. 183. DOUBLE MOTOR TRUCK BY SCHUCKERT & COMPANY.

The largest motors which have hitherto been made for railway work are those which have recently been constructed by the General Electric Company for some very powerful electric locomotives used by the Baltimore and Ohio Railway Company in running their trains in the tunnel under the city of Baltimore. These locomotives will be described in detail in a following chapter, but a word may be said here regarding the motors with which they are equipped.

They have six poles, but only two sets of brushes. The armature is

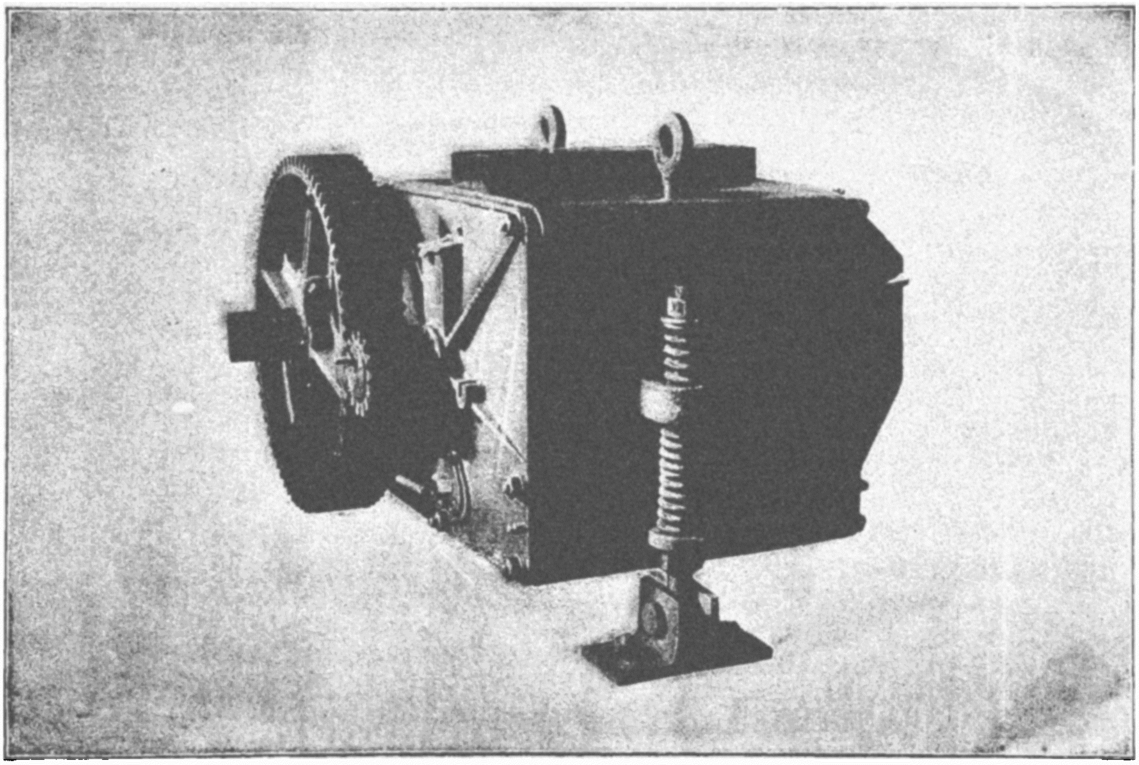


FIG. 184. MOTOR BY THE ALLGEMEINE ELEKTRICITATS GESELLSCHAFT.

wound on a quill which stands free from the axle proper, but is flexibly connected to it through a coupling, giving it perfect freedom of motion vertically and horizontally. The weight of the motor, including the armatures, is carried by heavy elliptical springs suspended from the frame of the locomotive.

The wheels are 62 in. in diameter. The locomotive is composed of two such trucks as the one shown in Fig. 186, each axle being driven by a motor rated at 300 horse-power. The maximum speed is 50 miles

an hour. The locomotive, complete, weighs 95 tons. The speed regulation is effected by a series parallel controller. Tests at the works of the General Electric Company at Schenectady have shown that for the same weight upon the drivers the electric locomotive will start a greater load than a steam locomotive. This is owing to the torque being constant throughout the entire revolution of the wheel.

GEARING.—It is of the greatest importance to secure an efficient method of reducing the speed of the armature and transmitting its movement to the axles. For this purpose double and single reduction spur

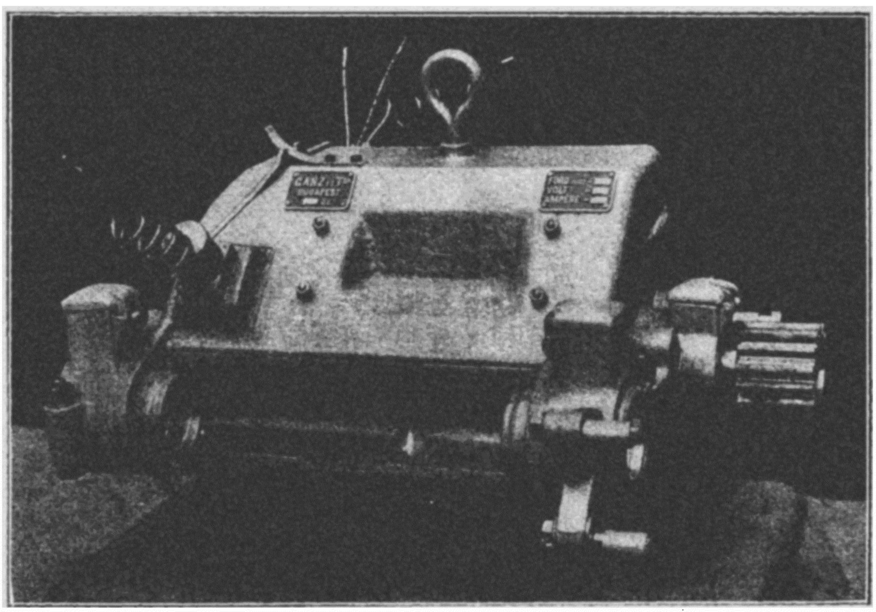


FIG. 185. MOTOR BY GANZ AND COMPANY.

gearing, bevel gearing, belting, single and double chain gearing, worm gearing, and other methods have been tried.

Of all these the single reduction spur and pinion is the most used, and has given excellent results, the efficiency being about 95 per cent. The pinions are now usually made of steel, and either pressed out whilst hot or cut in a milling machine and polished. The spurwheel is generally of cast iron, and the teeth milled. Phosphor bronze has also been used, but cast iron does as well and is cheaper. Fig. 187 shows one of Brown and Sharp's milling machines cutting two pinions.

To cut the teeth, milling cutters of the form of the tooth space are used, and it takes one to one and a half hours to cut the gears.

A steel pinion costs in America about 14s. A split cast-iron axle spurwheel with machine-cut teeth costs about 35s.

Instead of running the gear wheels in an oil bath, they were in the early days run entirely unprotected, the consequence being a very great wear and tear, inefficiency, and much noise. To do away with this noise, pinions made of raw hide were used ; these wearing out very quickly, were replaced by pinions constructed of alternate layers of raw hide and sheet iron ; these did not prove successful. As soon as they wore down slightly, the sheet iron strips acted as the teeth of a file and cut the gears to pieces.

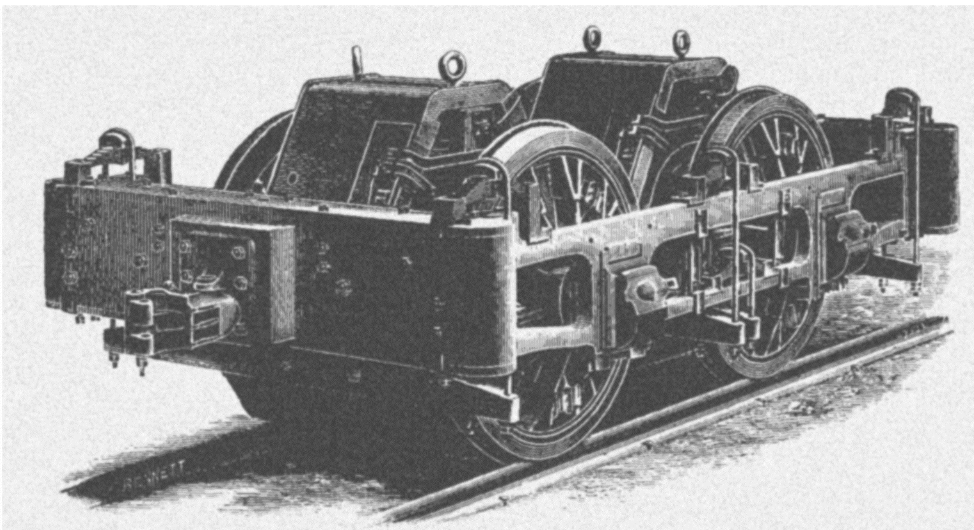


FIG. 186. MOTOR TRUCK FOR THE BALTIMORE AND OHIO RAILWAY COMPANY'S 95-TON LOCOMOTIVE. BY THE GENERAL ELECTRIC COMPANY OF AMERICA.

The design of tooth which has found nearly universal application is the "epicycloidal."

CHAIN GEARING.—Chain gearing has been used to a large extent by Messrs. Siemens and Halske on the Continent, either with double or single reduction. Although it may work satisfactorily at times, it is always apt to give trouble. It is often noisy, and the chain has always to be kept tight, as it stretches rapidly and there is danger of its coming off the pinion.

In one of the latest roads equipped by Messrs. Siemens and Halske at Genoa, they have used worm gear. The late Anthony Reckenzaun was a strong advocate of this form of gearing, and had designed a very effective type. A number of prolonged tests found the Reckenzaun gear to work

very satisfactorily (see *Electrical Review*, May 18, 1894), the average efficiency being between 85 and 90 per cent. For results of very interesting tests with this class of gearing, see William Sellers' experiments in ENGINEERING, vol. xlii., pages 285, 363, and 581. In Reckenzaun's gear the worm was turned out of a solid piece of steel, and was 6 in. in diameter, had a treble thread, and 6 in. pitch; the wormwheel was 15¼ in. in diameter, of phosphor bronze, and had 24 teeth, the speed reduction being eight to one, see Figs. 188 and 189.

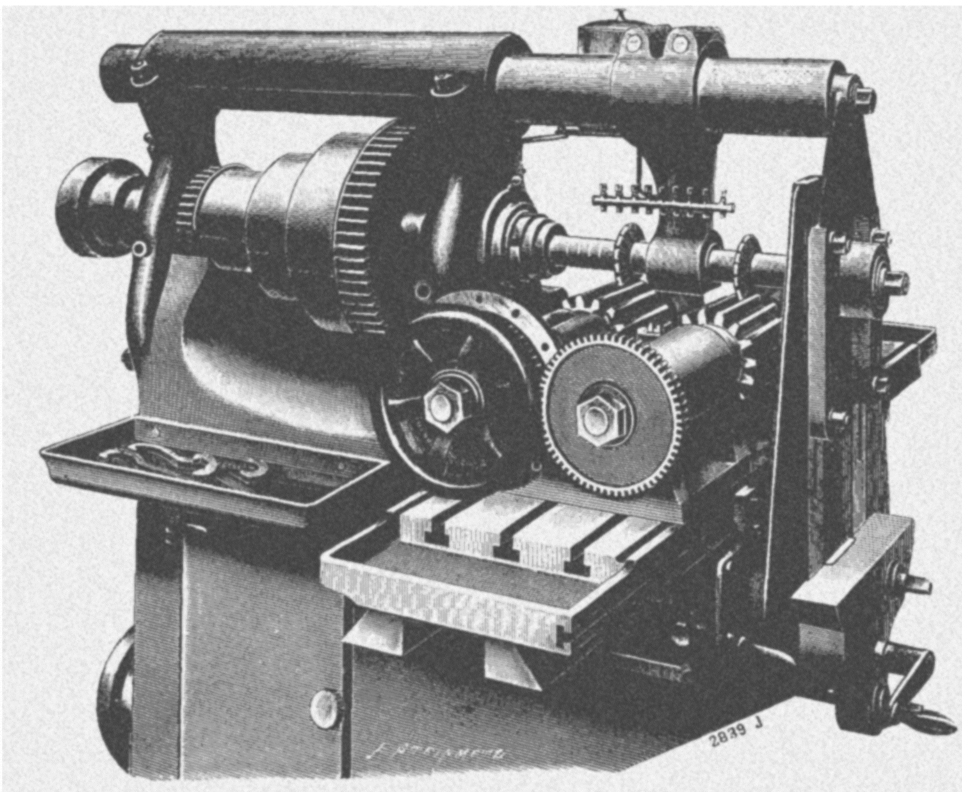


FIG. 187. MILLING CUTTER FOR MOTOR PINIONS.

Mr. Holroyd Smith, who designed and constructed the Blackpool road, is also greatly in favour of this kind of gearing, and has applied it on the last cars supplied by him to Blackpool. Among the advantages claimed for the worm may be mentioned that a much lighter and cheaper motor can be used owing to the large speed reduction effected.

Worm gear has, so far, only been employed on a small scale, whereas single spur and pinion is nearly universally employed.

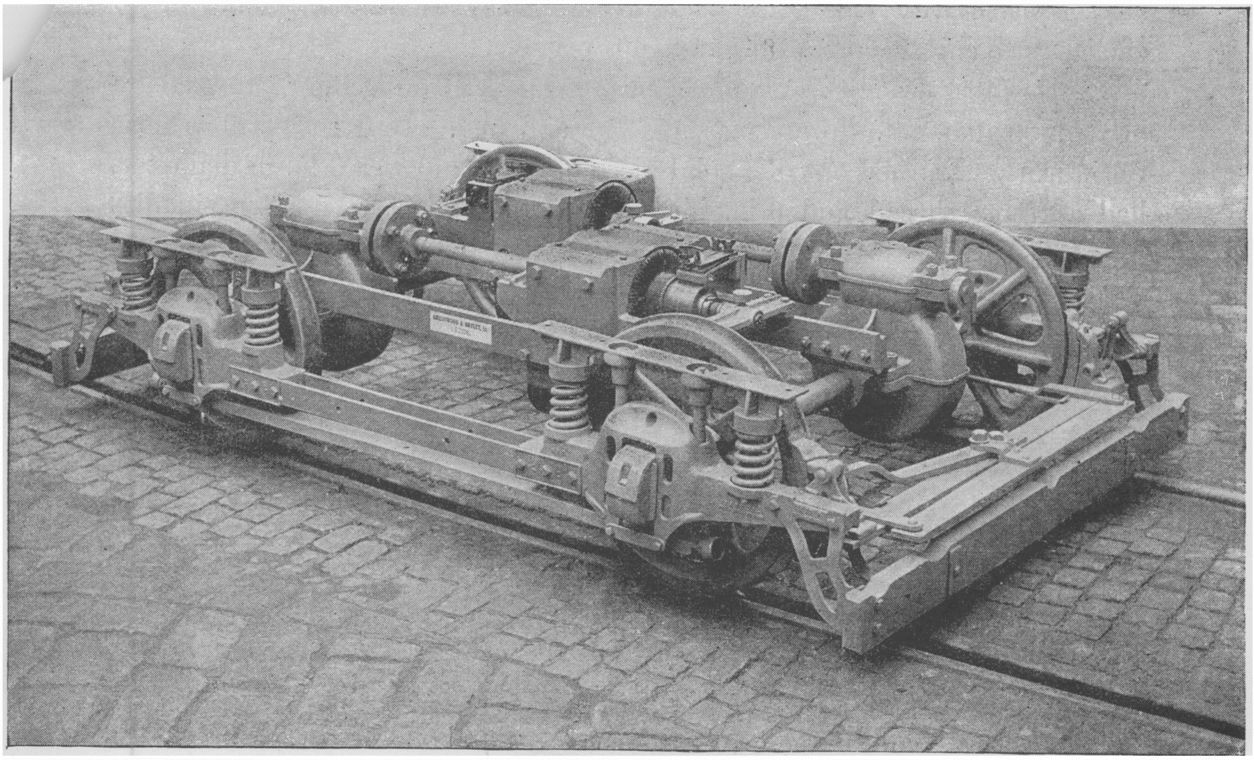


FIG. 188. DOUBLE MOTOR TRUCK WITH RECKENZAUN WORM GEARING.
(Constructed by Greenwood and Batley, Limited.)

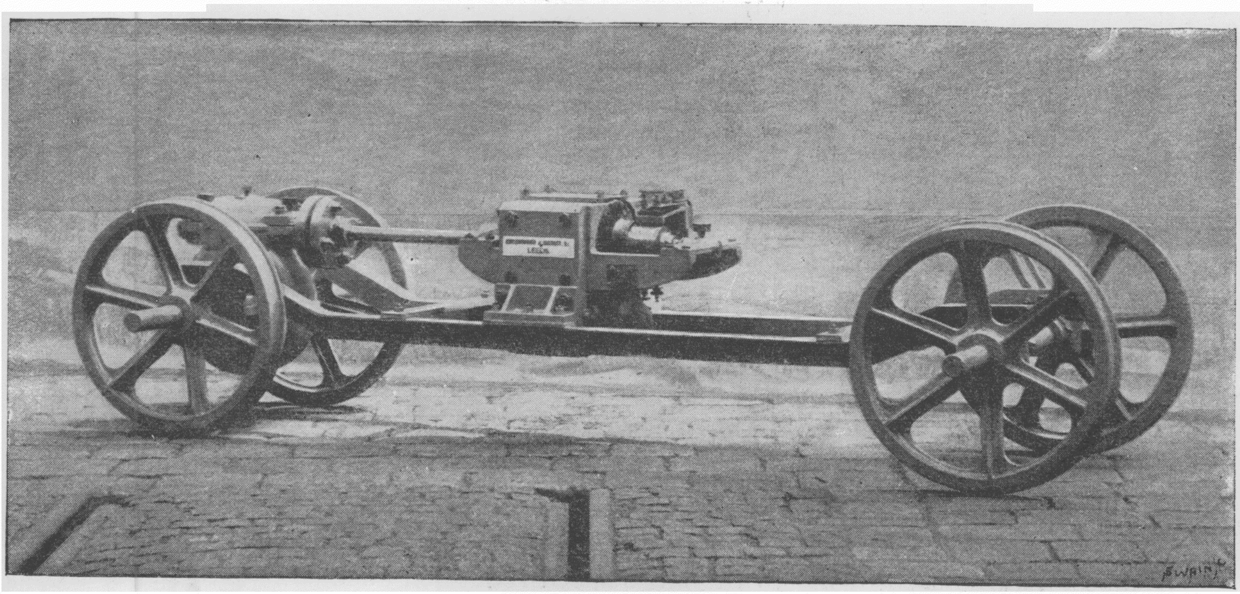


FIG. 189. SINGLE MOTOR TRUCK WITH RECKENZAUN WORM GEARING.
(Constructed by Greenwood and Batley, Limited, for Mr. Magnus Volk, Brighton.)

This being the case, worm gear has not had time to conclusively prove its merits or defects, and the results obtained at Genoa may therefore be looked forward to with interest.

In the first days of electric roads, when open double reduction gear was in use, the life of the pinion was found to be from two to four months (9,000 miles), and that of the spurwheels from four to ten months (29,000 miles); this amounted to a maintenance cost of about 0.09d. per car-mile.

Since the introduction of the single reduction motor with protected gear running in an oil bath, the life of the gearing has been more than doubled.

CHAPTER IX.

SPEED REGULATORS.

SPEED REGULATION AND CAR CONTROL.—One of the most important, and till recently the least satisfactory, of the devices connected with electric traction was the apparatus for speed regulation, consisting of resistances put in series with the motors on the car to decrease the current passing through the motors. This may be compared to regulating speed of a hydraulic engine by closing the throttle. Until lately this was, with few exceptions, the only method employed both in America and Europe. The resistances consisted of iron wire or plates, for the most part placed under the car, the amount of the resistance being regulated by a contact arm worked from either platform of the car by means of suitable gearing.

Among the disadvantages of this system may be mentioned the burning out of resistance and contacts, especially when the rheostat, as is generally the case, was exposed to mud and water; but the gravest fault of this system consisted in the loss of power due to heating effects, and which was proportional to the square of the current and simply proportional to the resistance. An idea of the importance of this quantity may be given by stating that it often equalled, and sometimes exceeded, the power necessary to propel the car itself.

Assume each motor is taking approximately 25 amperes at 162.5 volts. About 100 volts are used in overcoming the counter E.M.F., leaving 62.5 volts for forcing the 25 amperes through the motor against the resistance of field coils and armature. Now if the trolley pressure is 500 volts, we have, the total current used for the two motors being 25 × 2 = 50 amperes:—

Volts.		Amperes.		Watts.	
500	×	50	=	25,000	consumed from power-house.
162.5	×	50	=	8,125	consumed by the motors.
337.5	×	50	=	16,875	lost in resistances.

337.5 volts are used in forcing the 50 amperes through the resistance.

Compare these figures with the following obtained from the same car running under identically the same conditions, with the exception that the controllers were of the series-parallel type. The two motors each take 25 amperes at 162.5 volts as before, but the motors being in series, the total current is only 25 amperes.

Volts.		Amperes.		Watts.
500	×	25	=	12,500 consumed from power-house, a saving of 50 per cent.
325	×	25	=	8,125 consumed by the motors.
175	×	25	=	4375 lost in resistance.

16,875 Watts lost in resistance, parallel method.
4,375 Watts lost in resistance, series parallel method.
12,500 Watts saved by using the series-parallel controller; enough to run another car.

Of course it is understood that the above only applies to a car running on the first notch, *i.e.*, the two motors being in series.

The resistance method has, in all modern equipments, given way to the mode of speed regulation known as the commutated field and series parallel system of control; these two can either be used separately or in combination. Dr. Hopkinson and Mr. Anthony Reckenzaun in England, and Lieutenant Frank Sprague and Mr. H. F. Parshall in America, for many years advocated this method, and were engaged in designing controlling gear embodying this idea. The present "K" controller, which is considered the best device of this kind, owes a great deal of its success to the careful study of details, as well as principle, devoted to it by Mr. Parshall.

The commutated field method consists in subdividing the field coils into a number of sections and putting these into various combinations of series and parallel, thus varying their resistance, and consequently the current and speed. An outside resistance is used at starting, but is thrown out immediately thereafter. By this means it becomes possible to adjust the magnetic force of the field so as to make the motors give out power proportionately to the amount of work required for various speeds and conditions of track.

The range of speed without the use of a rheostat is fixed by the limit of temperature to which it is safe to heat the magnets.

The latest and most approved method is, as has already been stated, that known under the name of the series parallel system, and now universally adopted. This consists in the use of two or more motors per

car, which by means of a special device are thrown into different combinations.

Fig. 190 shows diagrammatically the various relative positions through which the motors pass from their first position, when they are in series with a resistance thrown in, to their last position for high speeds, where they are in parallel and part of the field is cut out, this accelerating the motors. The following are the various positions in what is known as the "K" controller of the General Electric Company:

1. Motors in series and all resistance in circuit.
2. Motors in series and half resistance in circuit.
3. Motors in series and all resistance cut out.
4. Motors in series and shunt around the fields.
5. Same as position 2.

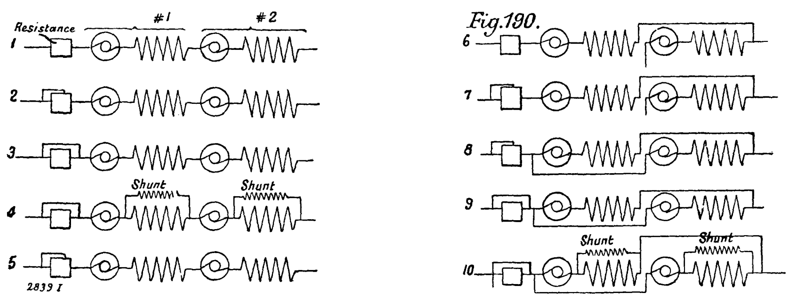


DIAGRAM SHOWING RELATIVE POSITION OF MOTORS IN SERIES-PARALLEL SYSTEM OF CONTROL.

6. One motor cut out, the other in series with half the resistance.
7. Same as 6.
8. Motors in parallel with half the resistance in series.
9. Motors in parallel with no resistance in series.
10. Motors in parallel with shunt round field.

The points 5, 6, and 7 are only graduating. The four economical running speeds are when the controller is in the positions 3, 4, 9, and 10.

The K 2 controller is now generally adopted. It is the same in outward appearance as the K controller, being identical in width and thickness, but about 2 in. higher over all.

It has one additional rheostatic point in the series, and also one in the parallel combination of the motors.

The circuit combinations made by the K 2 controller, point by point, are as follows:—

1st Point (1) Full resistance in series with motors (full field) in series.
2nd „ (2) $\frac{1}{3}$ resistance in series with motors (full field) in series.
3rd „ (3) $\frac{1}{12}$ resistance in series with motors (full field) in series.
4th „ (4) No resistance in series with motors (full field) in series.
5th „ (5) No resistance in series with motors (shunted field) in series.
Intermediate Points (6) $\frac{1}{3}$ resistance in series with motors (full field) in series.
„ (7) $\frac{1}{3}$ resistance in series with No. 1 motor (full field) No. 2 motor shunted.
„ (8) $\frac{1}{3}$ resistance in series with No. 1 motor (full field) No. 2 motor open circuited.
„ (9) $\frac{1}{3}$ resistance in series with No. 1 motor (full field) No. 2 motor open circuited.
6th point (10) $\frac{1}{3}$ resistance in series with motors (full field) in parallel.
7th „ (11) $\frac{1}{12}$ resistance is series with motors (full field) in parallel.
8th „ (12) No resistance in series with motors (full field) in parallel.
9th „ (13) No resistance in series with motors (shunted field) in parallel.

The K resistance is composed of six panels of sheet iron ribbon, three of these panels, beginning at R 1, having a resistance of about $1\frac{1}{2}$ ohm each. The remaining three measure about $\frac{1}{2}$ ohm each.

The K 2 resistance contains only four panels. The two central ones, each measuring about $\frac{1}{4}$ ohm each, are connected in series with the K resistance, the six panels of the K and the two in the K 2 thus constituting the starting resistance. Additional binding posts are provided, to admit of varying the resistance for special conditions.

The shunt method of weakening the motor fields for high speed is now used with the G. E. motors, and the outer panels on either side of the K 2 resistance are provided for the purpose of shunting the motor fields.

Each shunt panel measures 1.8 ohms ; a binding post in the middle of panel, and another one-third of the distance between the middle and top divide the panel, commencing at the bottom, into one section of .9, one section of .3, and one section of .6 ohms. These sections are connected together in series, and by properly arranging the connections it is possible to get resistances of 1.8, 1.5, 1.2, .9, .5, .3 ohms, and by connecting the halves of each panel in parallel, .45 ohms.

By means of these varied combinations the same shunt panels are adapted to various types of motors and windings.

The K 2 controller (although primarily designed for use with two motors) is also adapted, by reason of the additional rheostatic points, to the operation of a single motor. This is a special advantage where a single and double motor equipment are each used a part of the time on the same car.

The K R controller is particularly adapted to single motor railway equipments. In general appearance it resembles the K controller.

As ordinarily constructed, it has a single reversing switch for one motor only. If desired to operate two motors by rheostatic control, a double reversing switch can easily be included.

In inter-urban service, where very much higher speed is required, and where cars holding from 80 to 100 people run, it becomes necessary to use bogies, and to have four motors.

The K 2 controller can easily be modified for use with four motors by the addition of another reversing switch. It is then known as the K 4 controller.

The motors are connected in groups of two in parallel, each group corresponding to a single motor with the K 2 controller.

The standard K 4 controller is adapted for use with four motors only when two motors are permanently connected in parallel. Where greater variation in speed is desired, as for instance high speed gearing, with motors grouped in permanent series connection for city work, and changed to permanent parallel connection for suburban work, the K 4 B controller is used.

This controller, see Fig. 191, together with a commutating switch, admits of the motors being operated four in series, or parallel groups of two in series, and by changing the switch, series groups of two in parallel, or four in parallel.

The commutating switch is designed to be placed under the car seat, or platform, and is operated by a handle or key entirely separate from the controller.

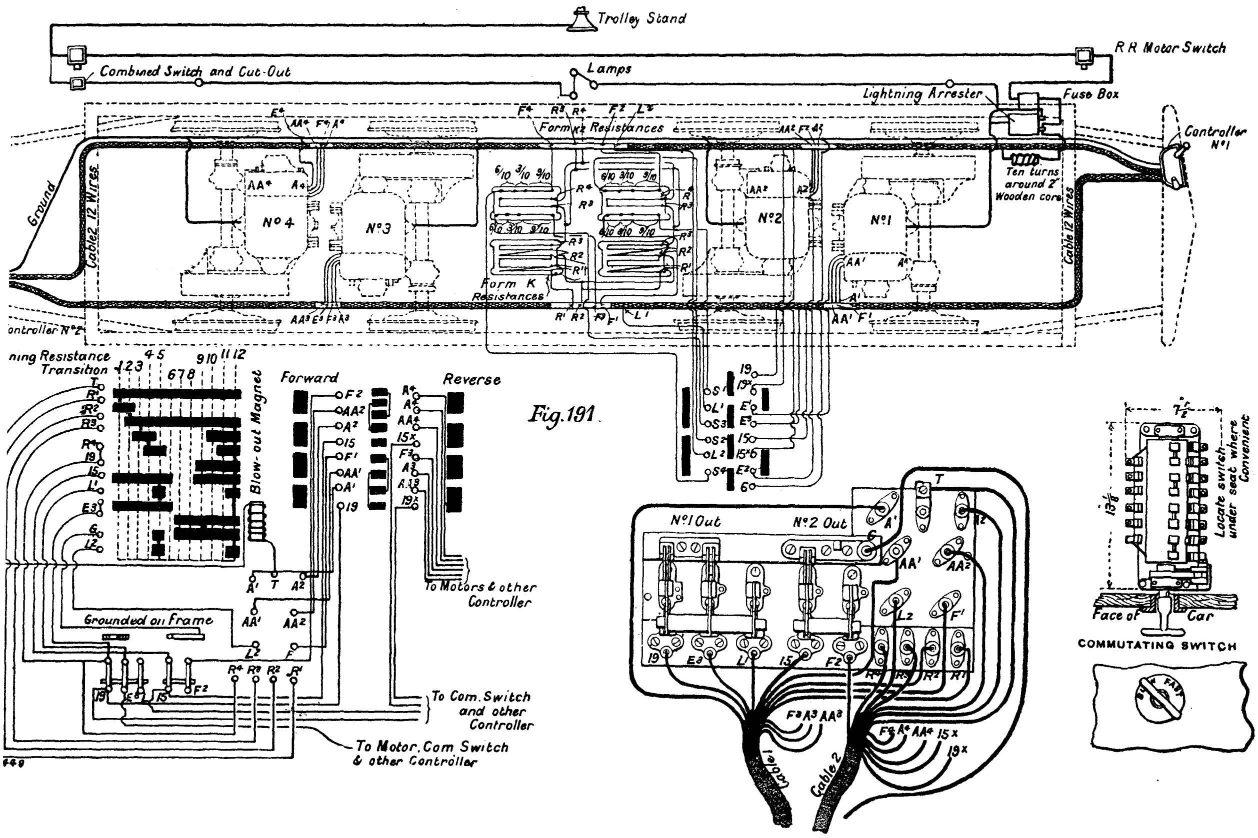
At first, instead of shunting the fields by means of a resistance, the so-called "loop" method was used, which consisted in cutting out part of the field in the positions where it now is shunted, the latter means having, in practice, proved more satisfactory.

In the case of the G.E. 800 motor the total starting resistance inserted is $4 \times 1\frac{1}{4}$ ohms and $2 \times \frac{55}{100}$ ohms $= 6.1$ ohms, or $4 \times R_1 + R_2 + R_3$ of the diagram, and the shunts used are 1.2 ohms between L and F; and $\frac{3}{10} \times \frac{3}{10} \times \frac{6}{10} = 1.2$ ohms, or as per diagram $S_1 = 1.2$ ohms and $S_2 + S_3 = 1.2$ ohms.

The object of their being thus subdivided is to enable the same con-

troller, resistance, and shunt box to be used in connection with all classes of motors.

The great gain is due to the counter-electro-motive force of the motors being used, instead of idle resistance, to cut down the current at starting, the starting torque at the same time not being decreased, but remaining the same as if the motors were in parallel and double the current used. As



K 4 Controller, Connections and Wiring.

already shown by the current diagram in a previous chapter, it is exactly at starting that the large call for current comes, and we see that by the series parallel method we at once reduce it by half.

The Tables XXXIX. and XL. show how great is the saving of energy effected by the series-parallel controller. Not only is there a great saving of power at starting, but also four different speeds are attained without the waste of current in resistances and with a high efficiency of the motors; this is also shown in the Tables.

TABLE XXXIX.—SAVING OF POWER BY SERIES-PARALLEL CONTROL ON ORDINARY RUN.

Mode of Control.	Time Occupied by Round Trip.	Number of Stops.	Number of Passengers.	Mean Current	Mean Voltage	Mean E.H.P.	Mean Starting Currents	Maximum Current.	Board of Trade Units per Car-Mile.	Average Speed in Miles per Hour.
	m. s.									
Series Parallel	69 40	60	98	22.0	465	13.7	32.3	85	1.085	9.5
Rheostatic ...	70 32	61	98	32.4	448	19.5	73.0	120	1.559	9.25

Maximum grade, 1.7 per cent. for 435 ft. Weight of car, 8 tons.

TABLE XL.—ECONOMY OF SERIES-PARALLEL CONTROL, STARTING AND RUNNING TEST.

Mode of Control.	Average Starting Current during First 14 Seconds, in Amperes.	Mean Current during Run, Starting excluded, in Amperes.	Mean Voltage.	Mean E.H.P.	Speed in Miles per Hour.	Board of Trade Units per Car-Mile.
Series-Parallel Control:						
Motors in series ...	18.3	12.8	440	7.5	9.5	0.589
Single motor ...	...	13.5	410	7.4	10.2	0.537
Motors in parallel ...	...	30.8	430	17.7	15.3	0.858
Rheostatic Control:						
With resistance in two motors	36.6	22.0	410	12.0	8.2	1.089
Two motors, no resistance	...	25.1	398	13.3	12.5	0.798
Two motors, weak field	...	39.8	385	20.4	15.0	1.015

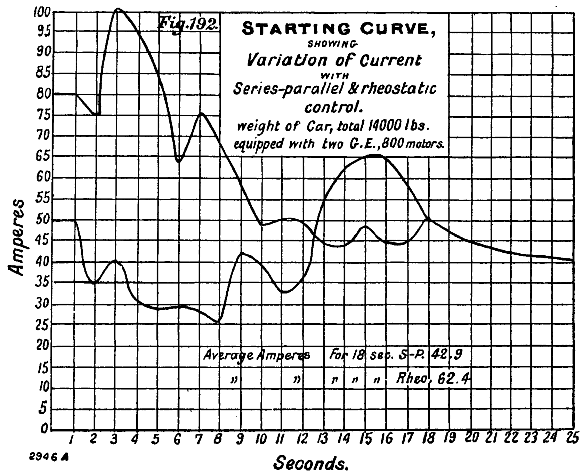
For these most interesting figures the writer is indebted to Mr. J. Hale, of Denver, Col., who carried out these tests with the greatest care, and the Tables given are compiled from a very large number made under the same conditions. In these each motor car had one trailer attached, and the passenger load was approximately the same, as also were the number of stoppages. For Fig. 192 the author is indebted to the courtesy of the General Electric Company; it shows the great loss of power which takes place with the rheostatic mode of control. With the series parallel method there is a saving of over 30 per cent. on the starting power required with the rheostatic control, or 0.05 of a Board of Trade unit every start; this, at an average of 15 stops a mile, which is not too much to suppose, would mean three-fourths of a Board of Trade unit every car-mile saved by the series parallel controller.

The great difficulty which had to be surmounted in this mode of control was purely mechanical, and consisted in the rapid burning out of the contacts on the controller due to the leakage of heavy currents at

high potential in a limited space, which takes place when changing from series into parallel. The arcs thus formed are, in the "K" controller of the General Electric Company of America, blown out by a very strong magnetic blow-out, of Professor Thomson's invention, as soon as formed; in fact, they are even prevented from forming.

The cylinder plates and contacts of the controller are made of thick iron stampings, as experience has shown that iron is better than brass. Fig. 193 shows a controller opened.

The reversing is done by a separate switch, and an interlocking gear is provided which prevents the motors being reversed till the current is turned off and the controller brought to the "off" position. A controller



is put on each platform of the car, but only one handle is provided, which can only be put on or taken off when the controller is in the "off" position.

Before adopting any type of motor, it is primarily necessary to find out what is the greatest amount of work it will be called upon to do.

For this purpose the various gradients and loads are taken, and calculations made to ascertain what the power required will be. Experience and numerous experiments have proved that for the English climate and grooved rails a tractive power of 30 lb. per ton is necessary. For speeds below 10 miles an hour, the effect of the wind may be disregarded, and the following formula used for the level:

$$\text{Horse-power on axle} = \frac{\text{Weight of car in tons} \times \text{tractive force in pounds} \times \text{speed in feet per minute}}{33{,}000}$$

For gradients the lifting power must be added, which is given by:

$$\frac{\text{Weight of car in pounds} \times \text{grade in per cent.} \times \text{speed in feet per minute}}{33{,}000}$$

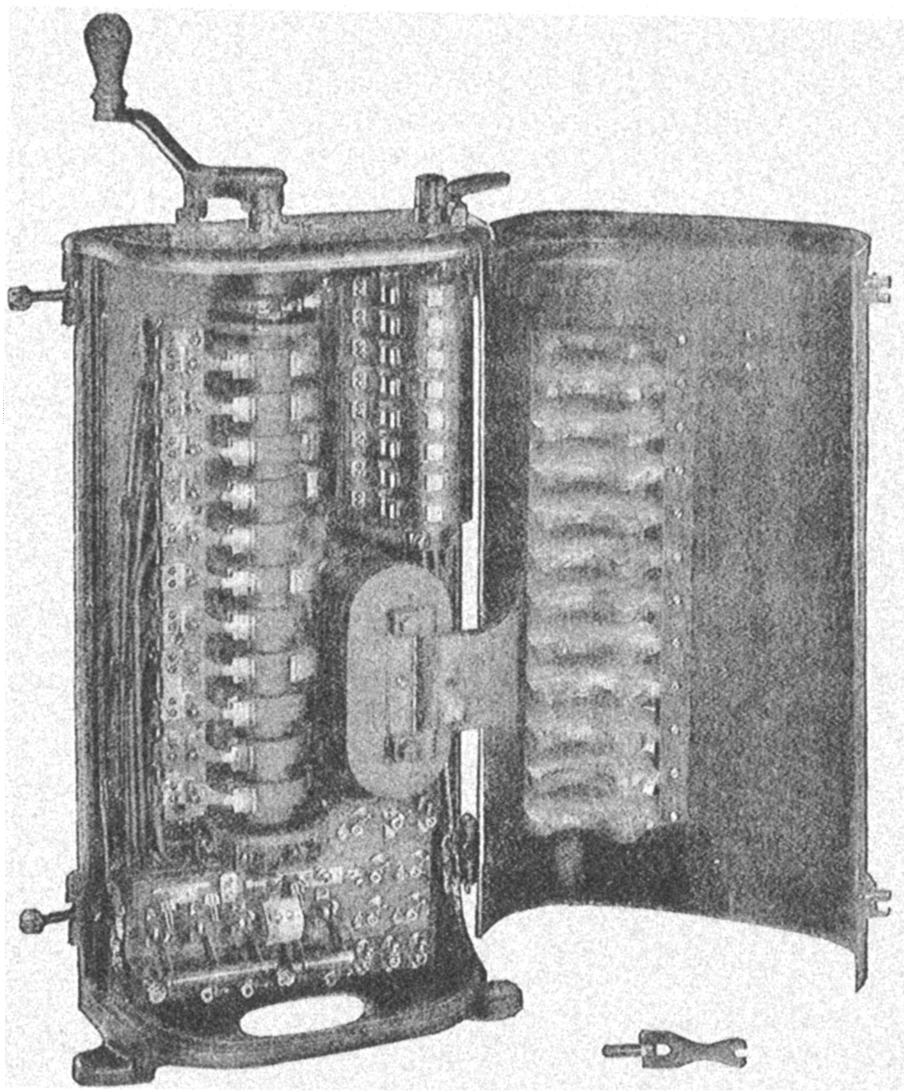


Fig. 193. General Electric Company's "K 2" Controller.

If we multiply the figure thus obtained by the efficiency of the motor in per cent., we have the power taken off the line.

It was directly proved by experiments made by M. Tresca on the tractional resistance of a tramway car, that the groove in the rail was the direct cause of a large portion of the resistance to traction.

The car, having four flanged wheels, with its load, was drawn over a portion of the Paris and Versailles Tramway, laid in macadam, when the tractional resistance amounted to 1-100th part of the gross weight, or 22-40 lbs. per ton. Subsequently, two of the flanged wheels, both on one side of the car, were removed and replaced by flat-tyred wheels, and the experiment repeated with the half-flanged car.

TABLE XLI.—Giving Results of M. Tresca's Experiments on Traction Coefficients.

	Tons.
Weight of 47 passengers, at 143 lb....	3.00
Weight of wheels	0.41
Weight of the car	2.26
Gross weight	5.67

The length of line traversed was a third of a mile, on a level; and the tractive force, at a uniform speed of $7\frac{1}{2}$ miles per hour, amounted to about 86 lb., equivalent to 1-147th part of the gross weight, or to $15\frac{1}{4}$ lb. per ton.

The resistance to traction at low speeds increases, of course, with the speed, though slowly. On ordinary railways, under ordinary conditions of curvature and of maintenance, the resistance of engines and trains taken together, as deduced experimentally by Mr. Kinnear Clark, may be taken as follows:

TABLE XLII.—Showing Variation of Traction Coefficient with the Speed.

12 lb.	per ton,	at a speed of	1	mile per hour.
13	"	"	10	"
14	"	"	15	"
$15\frac{1}{2}$	"	"	20	"

Here it appears that the resistance increases only by $2\frac{1}{2}$ lb. per ton. when the speed is raised from 10 miles per hour to 20 miles per hour.

Mr. E. Perrett experimented with a passenger car for 24 passengers, weighing 34 cwt., on four wheels $5\frac{1}{2}$ ft. apart between centres, on the Nottingham tramways. The force, by dynamometer, required to start the car, and the force required to keep it moving under different circumstances, are given in the following table :—

TABLE XLIII.—SHOWING TRACTIVE FORCE NECESSARY TO START CAR.

Grooves.	Line.	To start.	To keep moving.
		per ton. lb.	per ton. lb.
Clear	Straight and level	50	25
Very dirty	" "	66	50
Moderately Dirty	Straight up gradient 1 in 130	106	66
" "	Straight down gradient 1 in 130	57	34
" "	Curve 45 ft. radius up gradient 1 in 130	86	72
" "	Curve 45 ft. radius down gradient 1 in 130	62	50
" "	Curve 22 ft. radius up gradient 1 in 130	132	94
" "	Curve 22 ft. radius down gradient 1 in 30	95	65

From this statement it appears that on a straight line the starting force varied from 50 to 80 lb. per ton, according to the state of the rails—being less than those already mentioned. But it is probable that in this, as a private experiment, the starting was more gently effected than in the other instances. On the straight line, with clear grooves, the running resistance was 25 lb. per ton; and this was doubled, or increased to 50 lb. per ton, when the grooves were very dirty, or even when they were but moderately dirty, if the mean of the upward and downward pulls on the incline 1 in 130 be taken. Under the same condition of moderately dirty grooves, the effect of a curve of 45 ft. radius, averaged from the upward and downward pulls, was to raise the resistance from 50 lb. per ton to 61 lb. per ton; and that of a curve of 22 ft. radius raised it to 80 lb. per ton. If 25 lb. be deducted from each of the last three values for the effect of dirt in the grooves, there remain 25 lb., 36 lb., and 55 lb. per ton as the relative resistances with clear grooves on a straight line, a curve of 45 ft. radius, and a curve of 22 ft. radius; showing that the resistance on a 22 ft. curve is more than twice the resistance on a straight line.

Mr. H. Conradi has made some observations on the reduction of resistance due to the employment of rail cleaners. The gross resistance of each car at starting on muddy and dirty lines, straight and level, was from 80 to 90 lb. After the starting the resistance settled down to from 60 lb. to 70 lb. On curves, and passing places of from 25 to 30 ft. radius, the resistance was from 75 lb. to 85 lb. On very steep gradients and curves of this radius the resistance varied from 90 lb. to 100 lb. These trials were made

with a car weighing about $1\frac{1}{2}$ tons, carrying a varying load of 12, 19, and 22 passengers during the trial run, making an average total weight of above 3 tons.

To determine the tractional resistance of cars on rails cleaned, Mr. Conradi fitted a cleaner to two cars in ordinary condition and in ordinary service. The first car was started with the cleaner lowered and in action on the rails. Ten minutes later, the second car followed with a varying load of passengers up to 28 in number, also having the cleaner in action. This car started with an initial resistance of from 50 lb. to 60 lb. on the straight and level, and a running resistance of from 35 lb. to 45 lb.; on curves and at passing places, on the level from 50 lb. to 60 lb.; on curves on steep gradients from 70 lb. to 80 lb.

It thus appeared that, on rails previously cleaned by the first car, the tractional resistance of the second car, including that of the cleaner, was less by from 25 lb. to 35 lb.

Assuming the average gross weight of the second car, with passengers, to have been 3 tons, the tractive resistances were as follows :—

TABLE XLIV.—Showing Influence of Condition of Rails on Traction Coefficient.

	lb.		lb.	
Muddy and dirty, straight and level line, on starting ...	27	to	30	per ton.
Muddy and dirty, straight and level line, running	20	,,	23	,,
Same line, straight and level, car fitted with cleaner in action	12	,,	15	,,

The mean running resistance with the rail-cleaner in action is thus shown to be only 63 per cent., or less than two-thirds of the resistance under ordinary conditions.

Experiments were made, in 1890, on the Mödling (Vienna) Electric Railway, to ascertain the resistance on sharp curves, by means of a dynamometer placed between the two cars composing the train. The way consisted partly of grooved or tramway rails, and partly of Vignoles rails as used for ordinary railways. On a gradient of 1.50 per cent., or, 1 in 66.6, with curves of 100 ft. radius, and at a speed of 9.3 miles per hour, the resistance (irrespective of that due to the gradient) was from 17.6 lb. to 22 lb. per ton, averaging 19.8 lb. of train weight on the Vignoles section, and 26.4 lb. on the grooved section, and showing that the mean resistance on the Vignoles section was 6.6 lb. per ton, or 25 per cent. less than the grooved section.

The following Tables, XLV. to XLVII., will facilitate calculations.

TABLE XLV.—HORSE-POWER, SPEED, AND HORIZONTAL EFFORT.

Mechanical Horse-Power.	*Miles per Hour.* 2	4	6	8	10	15	20	25	30	40
	Feet per Minute. 176	352	528	704	880	1320	1760	2200	2640	3520
	Horizontal Effort in Pounds.									
2	375	187	125	93.7	75.0	50	37.5	30	25.0	18.7
3	563	281	188	140.6	112.5	75	56.3	45	37.5	28.1
4	750	374	250	187.5	150.0	100	75.0	60	50.0	37.5
6	1125	562	375	281.2	225.0	150	112.5	90	75.0	56.2
8	1500	750	500	375.0	300.0	200	150.0	120	100.0	75.0
10	1875	937	625	468.7	375.0	250	187.5	150	125.0	93.7
15	2812	1406	937	703.1	562.5	375	281.2	225	187.5	140.6
20	3750	1870	1250	937.2	750.0	500	375.0	300	250.0	187.5
25	4687	2343	1562	1172.0	937.5	625	468.7	375	312.5	235.3
30	5625	2812	1875	1406.0	1125.0	750	562.5	450	375.0	281.2
40	7500	3750	2500	1875.0	1500.0	1000	750.0	600	500.0	375.0
50	9372	4587	3125	2344.0	1875.0	1250	937.0	750	625.0	468.7

TABLE XLVI.—APPROXIMATE HORSE-POWER REQUIRED TO RUN FOUR-WHEELED, 6 FT. 6 IN. WHEEL BASE, 16 FT. INSIDE, STREET CAR. WEIGHT $7\frac{1}{2}$ TONS.

Grade in Per Cent.	Grade 1 in.	Miles Per Hour.									
		2	4	6	8	10	15	20	25	30	40
0	1 : 00	1.27	2.52	3.84	5.16	6.55	10.20	14.39	19.56	25.49	40.71
1	1 : 100	2.17	4.31	6.48	8.74	11.02	16.91	23.34	30.74	38.91	58.59
$1\frac{1}{2}$	1 : 66	2.61	5.20	7.82	10.52	13.25	20.25	27.79	36.31	45.60	67.51
2	1 : 50	3.05	6.09	9.15	12.31	15.48	23.60	32.26	41.89	52.29	76.44
$2\frac{1}{2}$	1 : 40	3.50	6.98	10.49	14.09	17.71	26.95	36.72	47.47	58.99	
3	1 : 33	3.95	7.88	11.83	15.88	19.95	30.30	41.18	53.05		
$3\frac{1}{2}$	1 : 26	4.39	8.77	13.17	17.66	22.18	33.64	45.65			
4	1 : 25	4.84	9.66	14.51	19.39	24.41	37.00	50.13			
5	1 : 20	5.73	11.45	17.19	23.02	28.88	43.69	59.05			
6	1 : 16	6.63	13.23	19.87	26.59	33.34	50.39	67.98			
7	1 : 14	7.52	15.01	22.54	30.18	37.80	57.09				
8	1 : 13	8.41	16.81	25.23	33.74	42.28	63.79				
9	1 : 11	9.30	18.59	27.91	37.31	46.73	70.47				
10	1 : 10	10.19	20.37	30.57	40.88	51.18	77.15				

TABLE XLVII.—HORIZONTAL EFFORT EXERTED ON CURVES AT 3 MILES AN HOUR. POUNDS PER TON.

Length of Wheel Base. Feet.	Radius of Curvature. Feet.							
	25	30	40	50	60	70	80	100
3.5	88.6	73.9	55.4	44.3	36.9	31.7	27.7	22.2
4	94.0	78.4	58.8	47.0	39.2	33.6	29.4	22.5
4.5	99.4	82.9	62.2	49.7	41.4	35.5	31.1	24.9
6	115.6	96.4	72.3	57.8	48.2	41.3	36.1	28.9
6.5	121.0	100.9	75.7	60.5	50.4	43.2	37.9	30.3
7	126.4	105.4	79.0	63.2	52.7	45.2	39.5	31.6

CHAPTER X.

CAR WIRING AND EQUIPMENT.

BESIDES the controller and reversing switch, there are several other devices needed on an electric car, such as main motor switches, lightning arresters, and impedance or "kicking" coils, starting and shunt resistance, &c.

Fig. 194 is a plan showing the connections of two motors as effected by the various positions of the controller. The contact cylinders of the controllers are developed and laid out flat, the dotted lines numbered from 1 to 10 showing the relative positions which the contact blocks and brushes occupy in the 10 points of the controller. The connections of the lighting circuit, magnetic blow-out, main cut-out, &c., are also clearly shown. Each motor is connected by switches to the controller, so that in case of one motor going wrong the driver or "motor-man" can instantly cut it out and run on with only one motor.

Both the starting and shunt resistances are composed of iron strips sandwiched with asbestos strips, and closely packed in an iron frame set in insulating and fireproof brick. For the fuses the use of thin copper wire is nearly universal, and in most cases they are put in so as to go at 50 amperes. The fuse-boxes are generally put under the platforms, and near enough to the dashboard to be readily accessible from the front.

On closed cars the main fuse or cut-out should be placed on the outside of the platform sill under one corner of the car. It is not good practice to place it under the seats or on either platform. It should be so secured to the car that the cover will hang vertical and swing upward. This will bring the trolley and motor terminals on the under side. The method of support may be either a back board or an angle iron.

On open cars the cut-out should be placed on one of the cross sills under the platform and easily accessible.

The main cut-out or motor switch is always in duplicate, and is worked from each platform, being generally put just over the motor-man's head, so

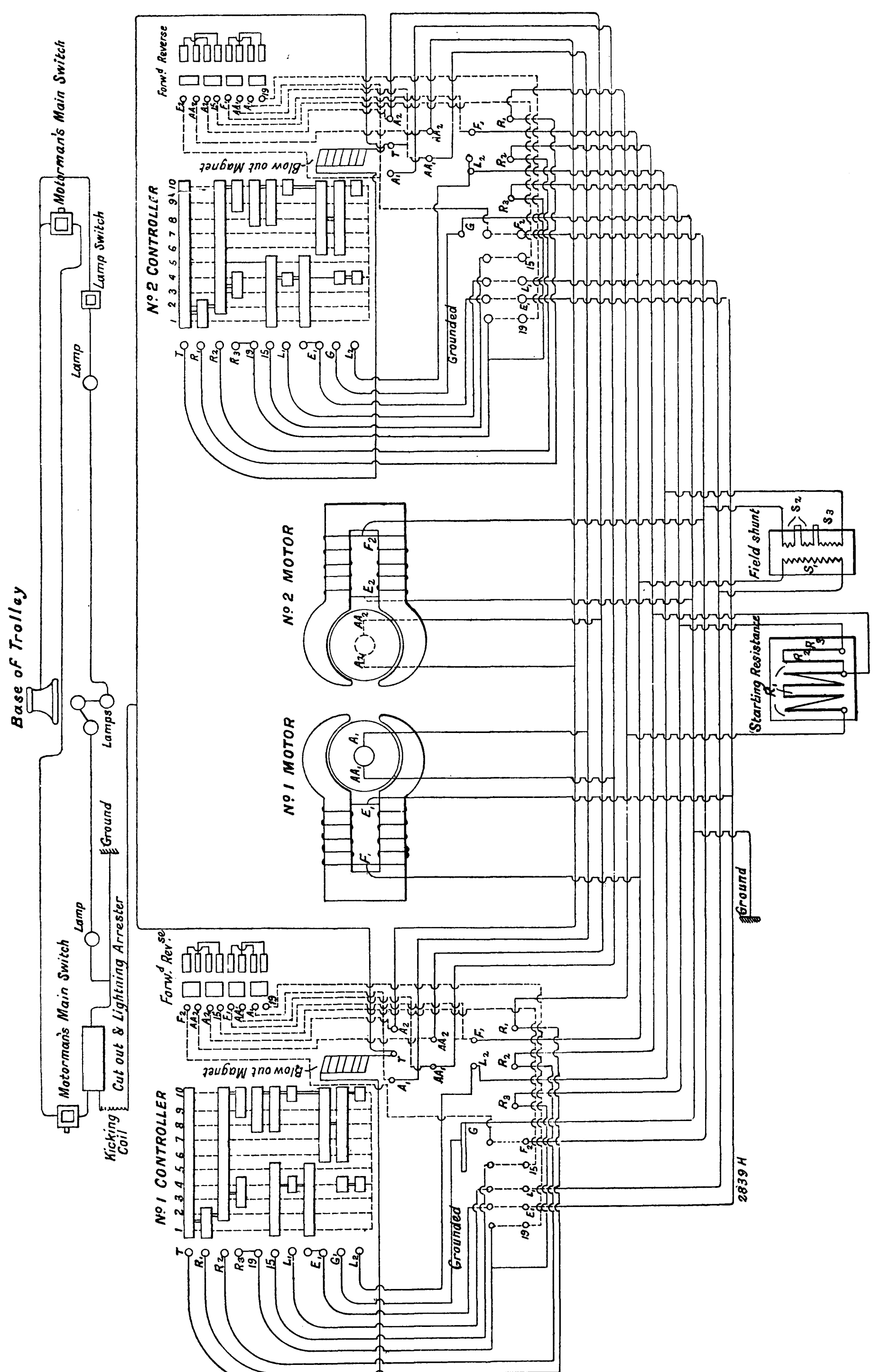


FIG. 194. CONNECTIONS OF DOUBLE MOTOR EQUIPMENT.

as to be easily reached by him. The current is always turned off here whenever the motor-man leaves his car.

The use of circuit breakers on cars, under such severe conditions as emergency reversals, may be recommended. In series parallel control of railway motors, or the old multiple control, the simple opening of the power circuit and then reversing the motors, and throwing them into parallel, was considered the most effective method for braking a car on account of the motors acting as generators.

This method, however, is not always attended by success, owing to to the fact that the motors have to "build up;" and in the event of the commutators being dirty or other high resistance in circuit, the "building up" is prevented or retarded.

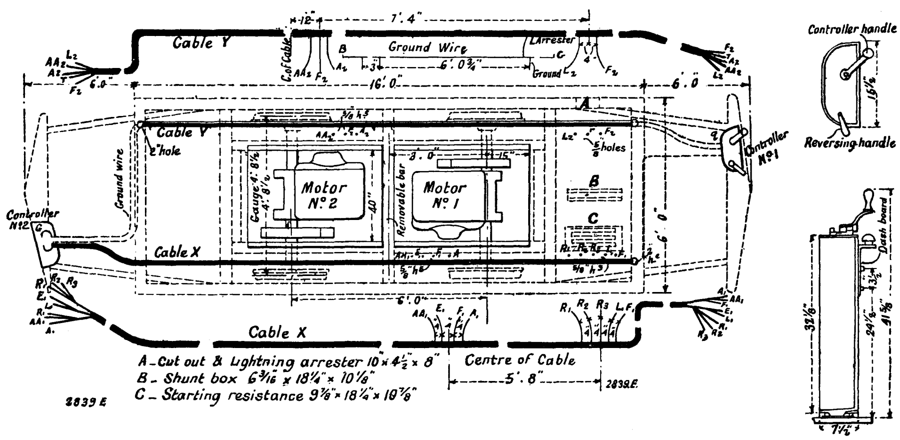


FIG. 195. DIAGRAM OF CAR WIRING.

This failure to "build up" has caused engineers, in some cases, to abandon this method. With a circuit breaker on a car, instead of opening power circuit as heretofore, reverse immediately; then the rush of current from power station will open the circuit breakers, but at the same time, give the motor, which is to be the generator, an initial magnetization, "builds it up," and the action is assured.

As shown by Figs. 195 and 196, the wires connecting a motor, resistances, shunts and controllers are all encased in one cable well taped and braided; each wire is cut off just at the right length, and is provided with a tag and number corresponding to numbers on the terminals of the motors and other apparatus, thus making it impossible to make any mistakes in connecting up. The car is lighted by one or more groups of five incandescent lamps put in series on the motor circuit, and provided

with a fuse and cut-off switch. The head lights of the cars are mostly oil, so as to prevent the possibility of their going out if, by any chance, the current were to stop.

TABLE XLVIII.—GIVING DATA OF CIRCUIT BREAKERS FOR ELECTRIC CAR USE.

Type.	Rating Amperes.		Adjustment Amperes.		
	Actual.	Nominal.	Steps.	Lowest.	Highest.
R. I....	60	80	25	100	175
S. I....	60	80	50	150	250

Each car should be provided with a lightning arrester and choking coil on the trolley wire side, as the series field coils of the motors are in most cases sufficient to prevent any damage from the ground side of the circuit.

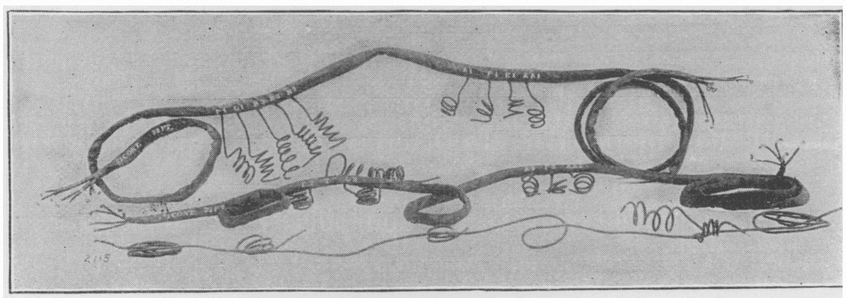


FIG. 196. SET OF MADE-UP CABLES FOR CONNECTING DOUBLE MOTORS AND CONTROLLERS.

The lightning arrester should be placed in a position where it will be protected from mud and water thrown by the wheels.

The kicking coil consists of ten turns of the main circuit wire wound about a wooden core, 2 in. in diameter and 6 in. in length. It should be connected between the lightning arrester and controller.

Fig. 197 shows the connections of an extremely useful and much-used type of lightning arrester, the Ajax, which has already been described, and need not be again referred to.

The Wurts non-arcing railway lightning arrester consists of two brass electrodes separated by $\frac{1}{2}$ in. of insulation, into which narrow grooves have been burnt. On the top of this a tightly-fitting insulating cover is fixed.

The principles on which this arrester is based are:

1. That experiment has shown that a static discharge will jump over a

non-conducting surface more easily than through an equal air space, and that a carbon groove over the non-conducting surface very much facilitates the discharge.

2. That an arc, in order to be maintained, must be fed by the vapours of the electrodes, and that if these fumes are prevented, the arcing will not take place.

The passage of an electric spark across an air gap is so instantaneous that it, so to speak, breaks through the air; but a pencil-mark across a piece of ground glass will very much facilitate the passage of the electrical discharge, although it will intercept the passage of a current. The

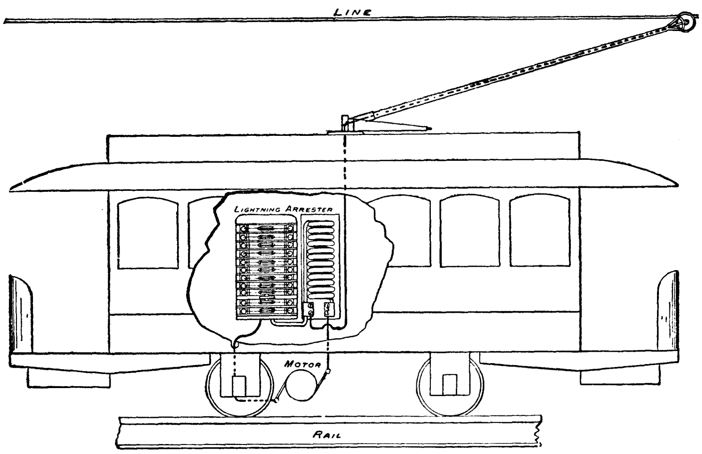


FIG. 197. DIAGRAM OF CAR LIGHTNING ARRESTER CIRCUIT.

resistance between the two conducting surfaces of the lightning arrester is over 50,000 ohms, so that it is not a cause of leakage.

Cables complete with suitable taps for connecting controllers, resistances, and motors for the shunt method of control, are preferably purchased made up ready for use. These cables are manufactured in lengths of 30, 32, 34, and 36 feet. Two cables are required for double motor cars, each containing seven wires. In addition, a separate ground wire is required. Each wire in the cables is composed of seven strands of small tinned wire to make it flexible and not easily broken. Two-way connectors should be used in connecting taps to motor leads, and soldered to the latter. In ordinary cases the required length of cable will be 6 ft. longer than the over-all length of a closed car, and 4 ft. longer than the over-all length of an open car, measured in both cases from dasher to dasher.

On a closed car four 2 in. holes should be bored through the car floor under the seats, one as near each corner of the car as possible.

On one side of the car, four $\frac{5}{8}$ in. holes should be bored in a line and 4 in. apart, to receive the taps from the cable to the leads of motor No. 1. The exact location of these holes depends on the type of motor used. The distance from the centre of the axle to the centre of this group of holes should be about $2\frac{1}{2}$ ft. On the same side of the car and in the same line four other $\frac{5}{8}$ in. holes should be bored 4 in. apart, to receive the taps from the cable to the resistance boxes. On the other side of the car three $\frac{5}{8}$ in. holes in a line and 4 in. apart, should be bored to receive the taps from the cable to the leads of motor No. 2, and on the same side of car and in the same line five other $\frac{5}{8}$ in. holes 4 in. apart should be bored to receive the taps for the trolley, resistance, and shunt for motor No. 2.

Each set of holes must be on the proper side of the car, and at such a distance from side sills as to be out of the way of wheel throw.

Measuring about 38 in. from the brake staff and a suitable distance inside of the dash rail, an oval hole 5 in. by $2\frac{3}{4}$ in. should be cut in each platform to receive the cables.

On an open car the wiring is carried under the floor and the cables brought up through the platforms.

In the standard car equipment one controller is placed on each platform on the side opposite the brake handle, in such a position that the controller spindle and the brake staff shall not be less than 36 in., nor more than 40 in. apart. The exact position depends somewhat on the location of the sills sustaining the platform. The feet of the controller are designed to allow a slight rocking with the spring of the dasher. Two $\frac{1}{2}$ in bolts secure the feet to the platform. An adjustable angle iron is furnished, to be used in securing the controller to the dash rail. A wire guard is also furnished, to be secured to the platform in such a position that the cables pass through it into the controller. A rubber gasket is furnished with each controller, to be placed between the wire guard and the platform to exclude water.

The wiring can be conveniently divided into two divisions: namely, roof wiring and floor wiring.

Roof wiring includes the running of the main circuit wire from the trolley through both main motor switches down the corner posts of the car to a suitable location for connecting to the lightning arrester and fuse box; also wiring the lamp circuit complete, leaving an end to be attached to the

ground. Whenever wires lie on the top of the roof, they need not be covered with canvas or moulding except to exclude water where they pass through the roof. In such cases, a strip of canvas the width of the moulding, painted with white lead, should be laid under the wire, and over this and the wire should be placed a piece of moulding extending far enough in either direction to exclude water. The moulding should be firmly screwed down and well painted.

This should be done while the cars are being built.

Floor wiring may be done after the car is completed without injuring the finish. Made up cables give far better protection to the wiring, and are easier to instal than separate wires, and should be used in the floor wiring if possible.

After the car bodies are prepared, the cables (one on each side of the car) should be run through holes in the platform, and the connections made to the motors and controllers, as shown in the diagrams.

After making connection to the controllers all slack should be pulled up inside of the car under the seats and held in place, preferably against the side of the car, by canvas or leather straps. Motor taps should project through the sills for attachment to the flexible motor leads just far enough to permit easy connection, leaving as little chance as possible for vibration.

All joints should be thoroughly soldered and well taped. The portions of the cables passing under the platforms should be supported by leather straps screwed to the floors or sills. Cables should never be bent at a sharp angle. The ground wire should run under the car floor rather than under the seats. On open cars all wires and cables must be run under the car, and should be well secured to the floor with cleats or straps.

A good joint can be made by separating the strands of the tap wire, and wrapping the two parts in opposite directions around the main wire. All openings in the hose should be sewed up as tightly as possible around the wires.

Separate wires can be installed if necessary, observing the following directions :

The floor wires on box cars should be placed under the seats as much as possible. In the few places where it is necessary for wires to cross, wood should intervene, in preference to a piece of rubber tubing or loop in the air. Where exposed it should be covered with moulding, but where moulding is used it should be carefully painted inside and out with good insulating compound to exclude water. The wire passing to the fuse box

should be looped downward, to prevent water running along the wire and into the box. Care should be taken to avoid metal work about the car in running the wires, and that nails or screws are not driven into the insulation.

Where wires are subject to vibration, as between the car bodies and motors, flexible cable must always be used. A certain amount of slack should be left in the leads from the motor to the car body, depending on their length. On cars with swivelling trucks a greater amount of slack is necessary. As slack gives greater opportunity for abrasion, care should be taken to leave only what is absolutely necessary.

Table XLIX gives a list of the various materials required to equip an electric motor car.

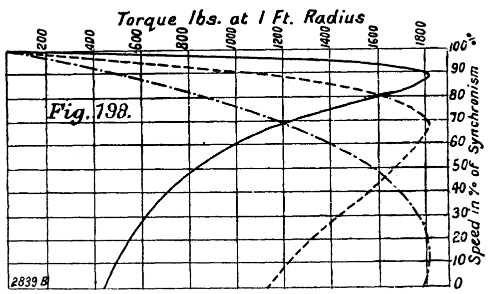
TABLE XLIX.—LIST OF SUPPLIES NECESSARY FOR THE ELECTRICAL EQUIPMENT OF A MOTOR CAR.

	Quantity.
Trolley complete	1
Main motor switches	2
Lightning arrester with self-induction or "kicking" coil	1
Starting rheostat	1
Shunt box	1
Series parallel controllers...	2
Controller handle	1
Reversing handle	1
Cable for connecting up, made up; having all the wires tagged and numbered	2 sets, each from 30 ft. to 36 ft. long.
Wood and brass corner cleats	—
$\frac{9}{16}$ in. rubber tubing	30 ft.
$\frac{3}{4}$ in. insulating tape	1 lb.
1 in. adhesive tape	1 ,,
$1\frac{1}{2}$ in. iron wood screws	
$\frac{1}{2}$ in. brass screws...	
No. 7/13 L.S.W.G. cable	75 ft.
Copper wire motor fuzes (50 amperes for 15 horse-power and 100 amperes for 25 horse-power motors) ...	20 per car
Solder	1 lb.

CAR LIGHTING.

Combined switch and cut-out	1
Keyless lamp sockets	5
No. 16 L.S.W.G. high-grade insulated wire	55 ft.
4 ampere fuze wire	—
16 candle-power incandescent lamps	5
Brass cleats and staples	—

For street railways it may be taken that no very great advantages would accrue from the use of alternating currents, as the motor would probably not be much lighter or cheaper. Besides the difficulty of efficiently regulating the speed, two overhead conductors at least would be necessary. But, apart from this, although polyphase motors have been designed which start under full torque, if this torque be exceeded the speed of the motor will fall rapidly. Fig. 198 shows this clearly, the three curves being the results of a series of tests on an induction motor—the top at full speed, the second with some resistance in the armature, and the lowest with



Result of Tests on an Induction Motor.

a greater resistance in. It will be noticed that in no case was the torque of 1,810 foot-pounds exceeded, and that the moment after this was reached it rapidly decreased. The best method for speed regulation so far has been found in putting a variable non-inductive resistance in the secondary circuit, the starting current being graduated by a variable resistance in the armature circuit. With our present knowledge, the only good motor for street car work is the continuous-current series-wound type now in general use. For long-distance railroads the advantages of polyphased or alternating currents are very great. The one noteworthy case of the application of alternating currents in connection with street railways is that of Portland, Oregon. This method is also employed at Dublin as hereinafter described.

CHAPTER XI.

MOTOR TRUCKS.

THE introduction of electric traction has revolutionised the construction of running gear. In former days, when horses and mules were the only motive power for street cars, it was considered quite sufficient to support the car body upon a single set of springs carried by the boxes, a simple bar being often the only connection between the two sets of wheels. The adoption of electric power and of cars equipped with single or double motors added immensely to the weight carried by the axles, and rendered it necessary that efficient methods be evolved for cushioning and suspending the motors over the axles while maintaining a rigid connection between motor and axle. At first the motors were rigidly attached to the bottom of the floor of the car body. This construction did not prove a success, for both car floor and motor deteriorated rapidly, access to the motors being also very difficult.

Experience demonstrated that the only effective method was to attach the motors to an independent truck frame, and to have all the mechanism of the car entirely independent of the car body.

The demand for this special class of work was soon met by a host of inventors, who from theoretical and practical knowledge, separate or combined, flooded the market with patents and devices. The result of a seven years' experience has sifted the useful from the useless, and it may now be fairly stated that the chief principles involved in the design of a thoroughly good motor truck, fulfilling all or most of the conditions imposed by electric traction, have been fully recognised, with the result that the electric motor truck has been brought to a standard. Truck building has become an independent business in America, although many car works make some form of truck.

Rigid frames had been employed in trucks for gas, steam, compressed air, and cable grip cars, but the conditions in all these cars are entirely different from those of electric motor cars. This experience was dearly bought by some of the earlier electric roads, as was testified by many a

scrap-heap composed of trucks which, after running but a few miles, had to be discarded.

The reliability or worthlessness of the motor trucks may mean the success or failure of an electric road, and to secure a good truck is quite as indispensable and important as to use a well-constructed and efficient motor. A motor truck comprises many parts, the most important of which are the side frames, springs, wheels, axles, boxes, bearings, motor bearings and suspension, sand-boxes, brakes, and safety appliances.

The following are the chief conditions which must be fulfilled by a truck suitable to electric traction :

1. The truck must be as light as possible consistent with rigidity and strength.

2. It must be thoroughly braced, so as to keep it stiff and square without having to depend in any way on the car body. The strains on a motor truck in rounding curves and when passing from the level to a gradient are extremely severe—much more so than with horse-cars, where the horses pull the car round on curves, and slow up on coming to a gradient.

3. The journal-boxes must be self-lubricating, require but little attention, and be dust-proof.

4. The brake action must be simple and effective, easily adjustable, and the brake shoes must be replaceable at a moment's notice, and be mounted in such a way as not to be influenced by the spring motion of the car.

5. The truck must be constructed in such a manner as to render access to all parts easy, and to admit of motors, wheels and axles, journal-boxes, brake gear and the like, being easily removable, without having to dismember the truck. Strains on bolts should be avoided as much as possible.

6. The car body must be attached to the truck in such a manner as to be readily removable by the loosening of a few bolts.

7. Springs must be arranged so as to cause the running of the car to be equally smooth when empty as when fully loaded, and to prevent the pitching and rolling motion to which street cars are so liable, due to sharp curves and rough roads. This is a very important point, not only for the comfort of the passengers, but also to prevent rapid deterioration of the car wiring and car bodies; the former of which is very likely to cause grave results to the motors by causing short circuits.

8. An appropriate choice of wheels is most important.

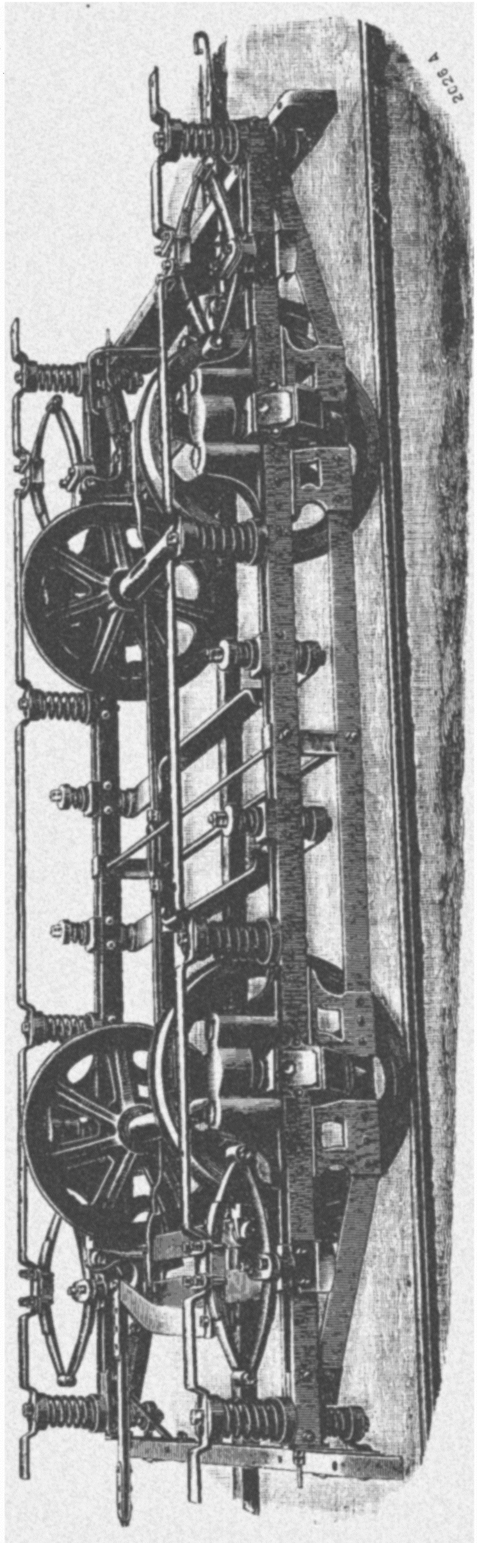


Fig. 199. "Peckham" Standard Cantilever Motor Truck.

All these essential features must be satisfied by any given truck before it can be used in connection with electric traction. There are three essentially different forms of truck, which, although conforming to the above specifications, do so in different ways, and which are employed according to the conditions demanded by the particular track and service. These three types are the following:

1. The rigid four-wheel truck.
2. The radial six-wheel truck.
3. The four-wheel bogie truck, for eight-wheel cars.

In the rigid four-wheel truck, where the wheel base is naturally restricted, it is of the very greatest importance to have an arrangement whereby the car body is supported as far outside the wheel base as possible, and to diminish as much as may be, by the judicious use of springs, the destructive effect of jolting, both on car body and motor equipment.

The "Peckham" Four-Wheel Motor Truck.—The first manufacturer to devote exclusive attention to the construction of trucks for electric and cable railways, was Mr. Edgar H. Peckham, of New York, and the works of the Peckham Motor Truck and Car Wheel Company have turned out a very large proportion of the trucks which have given successful results in America

and Europe. It will be seen from the illustrations that the same general principles are adhered to in all the different styles of trucks made by this company. The main feature of the Standard and Extra-Long Peckham Trucks consists in the extended spring base supporting the car body, and supported in its turn by a cantilever truss from underneath, the object kept in view being to prevent the "pitching" and "rolling" movement of the car, and at the same time to provide a better support for the extremities.

The side frames are constructed of flat wrought steel bars, riveted to

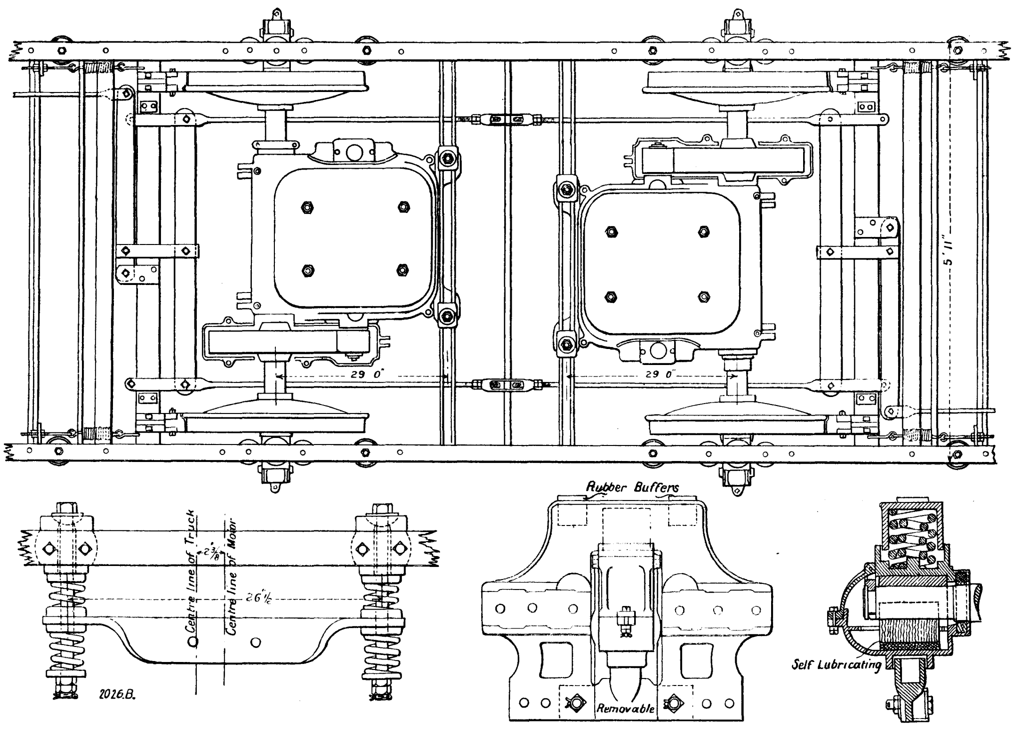


FIG. 200. DETAILS OF "PECKHAM" STANDARD" DOUBLE-MOTOR TRUCK.

the soft steel yokes or pedestals which support the frame on the axle-boxes. All the rivets are driven hot, and the whole is nothing less than a piece of bridgework. To have as long a supporting base as possible, end extension bars are riveted hot to the suspension yokes, and these are supported from beneath by steel truss bars, firmly riveted to the end of the extension bars and to the lower part of the yokes.

The inferior portions of the yokes are connected by removable wheel-pieces of cast iron, held in position by two bolts provided with split pins, which can easily be removed whenever it is required to remove the axles

or wheels. When these pieces are in place, they form with the framework one continuous truss, resembling both in appearance and construction a truss of a cantilever bridge.

The base of the pedestals or yokes is provided with the removable repairing piece which is secured in place between the jaws of pedestals by bolts, and can be easily removed whenever it becomes necessary to remove the wheels and axles from the truck for repairs.

Its bearing parts are accurately machine-fitted to correspond to the bearings of the pedestals, which are also machine-fitted. It is provided with a cylindrical projection, which fits loosely into a cylindrical opening in the bottom of the oil box.

The self-lubricating dust-tight journal-box is so constructed that oil or grease may be used as desired. To make it absolutely dust-tight the bearing for the cover is machine-fitted, and between the bearings and the

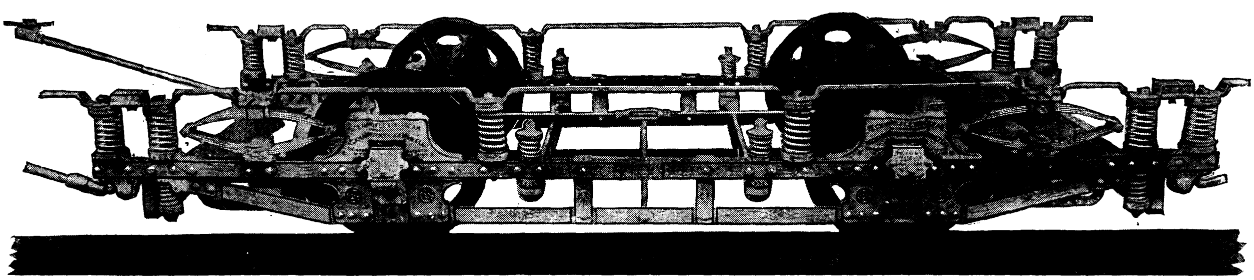


FIG. 201.—"PECKHAM" EXTRA-LONG CANTILEVER EXTENSION MOTOR TRUCK.

cover is inserted a packing of leather. It is provided at the back end with a dust-tight packing which rests upon the axle.

The top bar, on which the car body rests, and to which it is bolted, is constructed in one piece, and it is supported on the main framework by a set of elliptical and spiral springs. Over the points where the springs are attached to the top bar there are depressions in this bar, so that the spring bolts can be got at easily and the springs removed when necessary without having to jack up the car body. One double elliptic spring is placed on the outside of the yoke box, and this is calculated so as to support the car body when light, and yet not to be too stiff to give an easy-running car at light loads. At these loads the spiral springs do not act, and they only come into play when the car becomes loaded. When loaded, the double elliptic spring doubles up and loses its elasticity, owing to the increased leverage caused by the flattening out of the spring.

The weight of the car is then taken by the spiral springs. This causes the car to be as easy-running when heavily loaded as when empty; an advantage which cannot be over-estimated on cars which may have to run over rough roads and with very variable loads. Besides these springs, a coil spring is provided at each extremity, which takes the up-thrust and acts as a dashpot, deadening and rapidly stopping any pitching motion which might arise by the car bumping, or from a number of passengers getting on or off at once at one end. In case of an emergency overload, which might cause the top bar to rest on the top of the yokes, two rubber cushion springs are fixed on the top of each of these.

The framework just described does not rest directly on the journal-boxes and axles, but is supported from there by a double set of spiral springs, one inside the other, which take up the first effect of any shock caused by rough tracks, the first spring taking up the smaller shocks, and the second only coming into action if an unusually heavy one should be encountered.

One spring is wound to the right hand and the other to the left, this being done to counteract the torsional strain which always arises from a shortening of spiral springs. These springs are so designed that the load which each has to take produces the same strains and compression of both, and also so that when they reach the maximum compression the successive coils of both springs come in contact at the same moment. The motors are hung from crossbars suspended from the side frames by coil springs, and provided with a set of springs to take the up-thrust which is caused by shocks, and to prevent oscillation.

These trucks have been adopted in Great Britain by the Bristol, Dublin, Coventry, Leeds and Guernsey Electric Tramways, and by a large number of Continental and Colonial installations, notably Brisbane. They have also served as the model from which many Continental manufacturers have taken the main features of their running gear.

A lighter form of Peckham truck, used for trail cars or very light motor cars, is shown in Fig. 202, and is known as the "Excelsior" truck.

It is of great importance to have trail cars mounted on proper trucks which prevent rolling and pitching, this action being very bad for the motor car, and also entailing loss of power.

There are three important component parts of a truck which merit special attention—the springs, axles, and wheels. Till the introduction of mechanical—and more especially electric—traction, rubber was nearly

universally used for street car springs. The next step was to use coil springs with rubber cores, the latter serving to graduate the former. Coil springs wound in conical and barrel shape were also used, the property of these being that the large coils acted under light loads, the smaller ones only coming into action as the load increased. The combined use of elliptical and spiral springs is now nearly universal, the former being more elastic, although not having so wide a range as the coil springs, and also being stiffer sideways than the coil springs, and better preventing the rolling motion of the car.

The construction of reliable springs has been brought to great perfection in America. The tempering of springs is generally effected by first dipping them in oil for a short time, when at a cherry heat, and then taking them out and allowing them to cool gradually. The utility of the

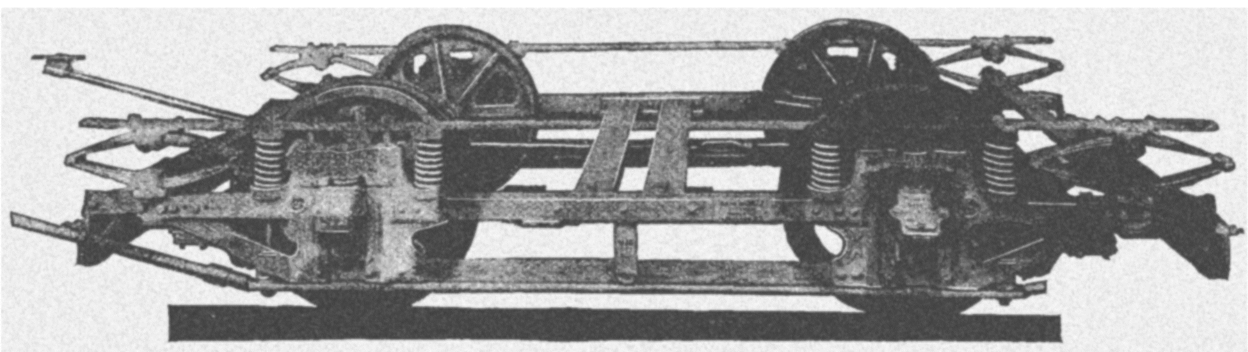


FIG. 202. "PECKHAM" EXCELSIOR MOTOR OR TRAILER TRUCK.

springs is not confined to making riding easy to passengers. Their greatest advantage is the protection they provide to car body, motors, and track from sudden concussions and jolts.

The difference between riding in one of the old-fashioned horse-cars and in an improved American electric car is quite as great as between riding in an old suburban railway carriage and a Pullman car, in the construction of which the advantages of double spring suspension by coil and elliptical springs are displayed to the fullest extent.

The axles used are either of iron or steel. For street railway service, rolled axles are mostly used. As in steam railroad practice, the wheels are pressed on to the axles under heavy pressure. The conditions which axles have to fulfil in street railway service are very similar to those of the ordinary steam railroads, and the practical experience gained on the latter holds good on the former. Axles are by no means uniformly loaded as we

might infer. Wöhler found by experiments that, owing to oscillations and unevenness of tracks, the difference of load between the two wheels reached 0.45 of the total load on the axles; and if this is the case on railroads, it is much more so on street railways, with their comparatively rough and uneven tracks. The design of a good axle depends, therefore, just as much, or more, on practical experience as on calculation. Axles do not generally develop flaws till after they have been in service for some time, which makes it important to allow a very great factor of safety in their construction.

Owing to the pounding over rail joints and obstacles on the track, and to the great number of stops and starts and resulting repetition of torsional strains, the metal of the axles crystallises after some time of service, and becomes very brittle and liable to break. This has caused many street railway companies to make it a rule to take the axles out of motor cars after, say, 18 months' running, and put them on to trailer cars, as breakage on a motor is much more serious than on a trailer. Axles of rolled steel with .16 or .17 per cent. of carbon have been found to give very good results if properly dimensioned, and they have the advantage of being much cheaper than the forged axles. To get a good fit for the motors and gear wheels, axles must often be turned down to within a thousandth of an inch. This requires the metal to be perfectly uniform and homogenous.

The "Taylor" Four-Wheel Truck is shown in Fig. 203. The side frames are formed of two flat wrought iron bars placed edgewise and bolted together; the two side frames are connected together at their extremities by trussed bars, and in the centre by two heavy wrought iron bars placed edgewise, which also serve as supports for the motors. To the side bars are firmly bolted the pedestals or yokes, which rest on the axle-boxes and support the truck. On each side of the bottom of this yoke there are sockets which receive adjustable angular braces, or struts, supporting and strengthening the ends and centres of the side frames.

A strong adjustable tubular iron stay connects the bottom of the yokes, fitting into sockets at that point. It will thus be seen that the two side frames resemble in construction a bridge truss, distributing the weight of the car, and the strains from motor and wheels, over the entire frame of the truck.

Above, and resting on the axle-boxes and between the side bars, are half-elliptical springs, fitted into yokes at their ends. These carry all the

weight of the truck, and serve as cushions. At each end of the truck frame a pair of double elliptical springs are securely fastened to the trussed end bars. Upon these springs, but not fastened to them, is placed the cross-beam of the car body, fixed to it by angle-irons at each end. The car body is fastened to the truck by king-bolts placed in the centre at each end, and passing through the bolster and end bar. These king-bolts

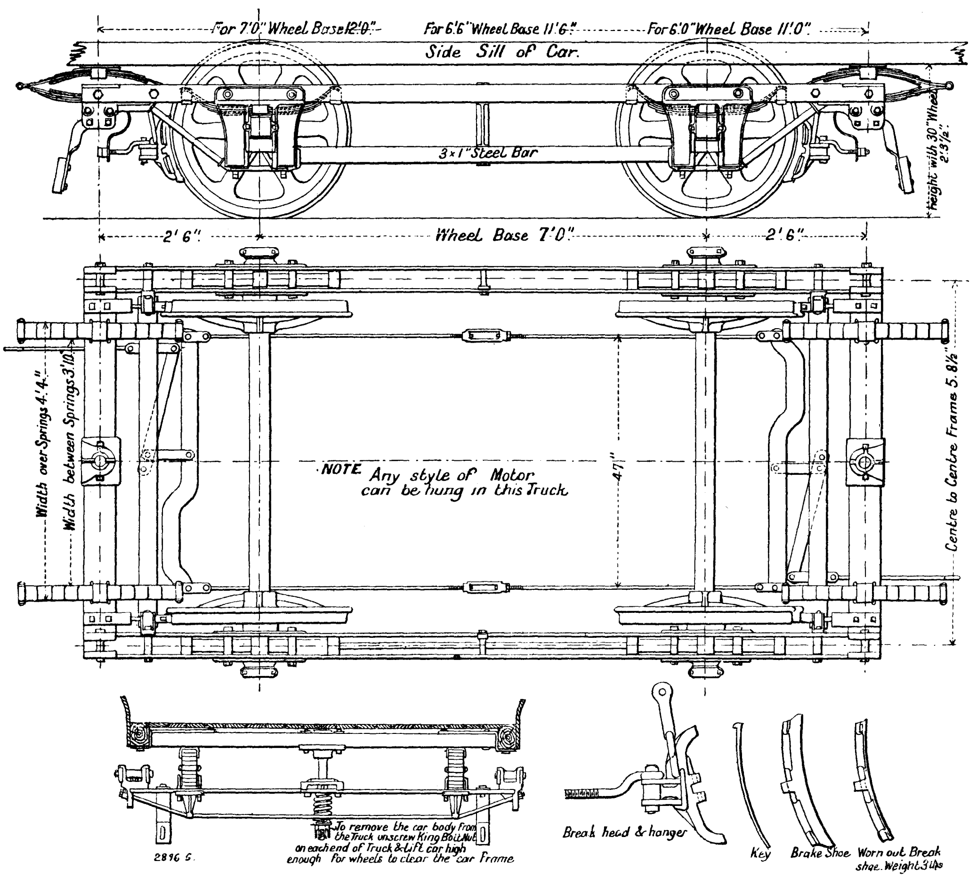


FIG. 203. "TAYLOR" TRUCK.

are furnished with a special coil spring bearing upward against the end trussed bar, these acting as dashpots, and preventing pitching.

The wheel base varies from 6 ft. to 8 ft. 6 in. for closed cars of from 16 ft. to 20 ft., and open cars of from 24 ft. to 34 ft. With 30-in. wheels, the height from the top of the rail to the bottom of the car sill, with car body empty, is $27\frac{1}{2}$ in.

THE "LORD BALTIMORE" FOUR-WHEEL TRUCK has also a good reputation for easy running and simplicity. Fig. 204 gives a good idea of its

construction. The side frames are steel T-beams pressed to the required shape by hydraulic pressure, and 5 in. deep by 4 in. wide on top. They are supplemented from a point 15 in. inside of centres of the axles, to the ends, by cast-steel yokes which fit into the T-pieces, taking a bearing both under and over them. The jaws of these yokes fit into the axle-boxes, insulated from them on all sides by rubber. All the brake rods and connections are above the axles. The truck is fitted with half-elliptic springs, to which the car body is flexibly connected. The spring base thus

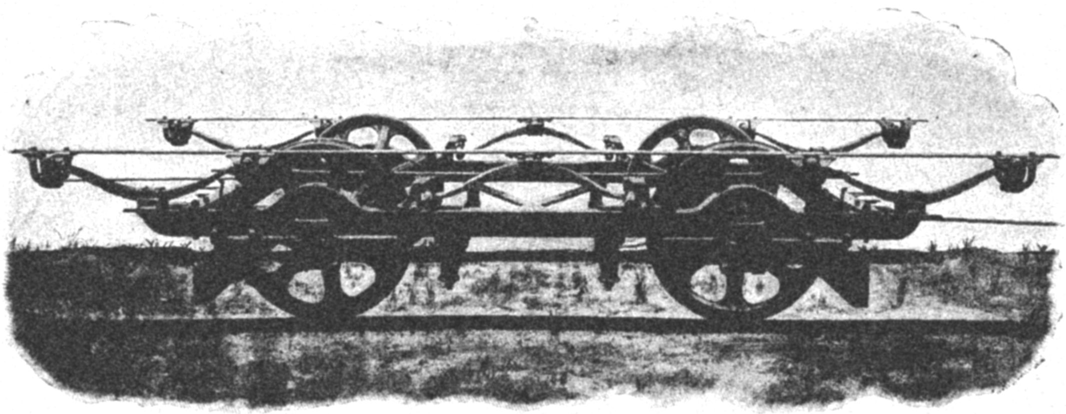


FIG. 204. "LORD BALTIMORE" TRUCK.

secured is 8 ft. longer than the wheel base. Fig. 205 is a section through the journal-box used with this truck. The box is a single casting, with a circular opening at one end for the passage of the axle, and a slot at the top perpendicular to the axle. The axle is kept in place in the box by means of a fork passed in through the slot at the top of the journal-box, and fitting into an annular groove cut near the end of the car axle, and into a groove in the walls of the box. After the fork has been slipped in its place, a piece of fibre is put on the top of it to prevent its coming loose, and a cover is screwed over the opening in the box through which it has been admitted. A felt wick is used for lubricating. The dust is kept out by means of washers kept in place by springs.

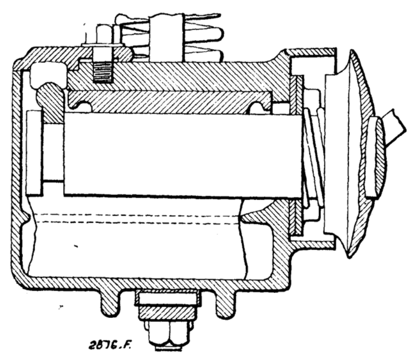


FIG. 205. "LORD BALTIMORE" JOURNAL-BOX.

The provision for play is outside the box, within the jaw of the yoke fixed to the side frames.

The "Imperial" Four-Wheel Truck is shown in Fig. 206. The frame is of cast steel, and has an **I**-section extending from end to end of the truck, joined together at the ends by means of an **I**-beam and fishplates. The pockets to receive the springs are cast on the frame, as well as the lugs for the under-truss. The car frame is hung by coil springs on the top of the

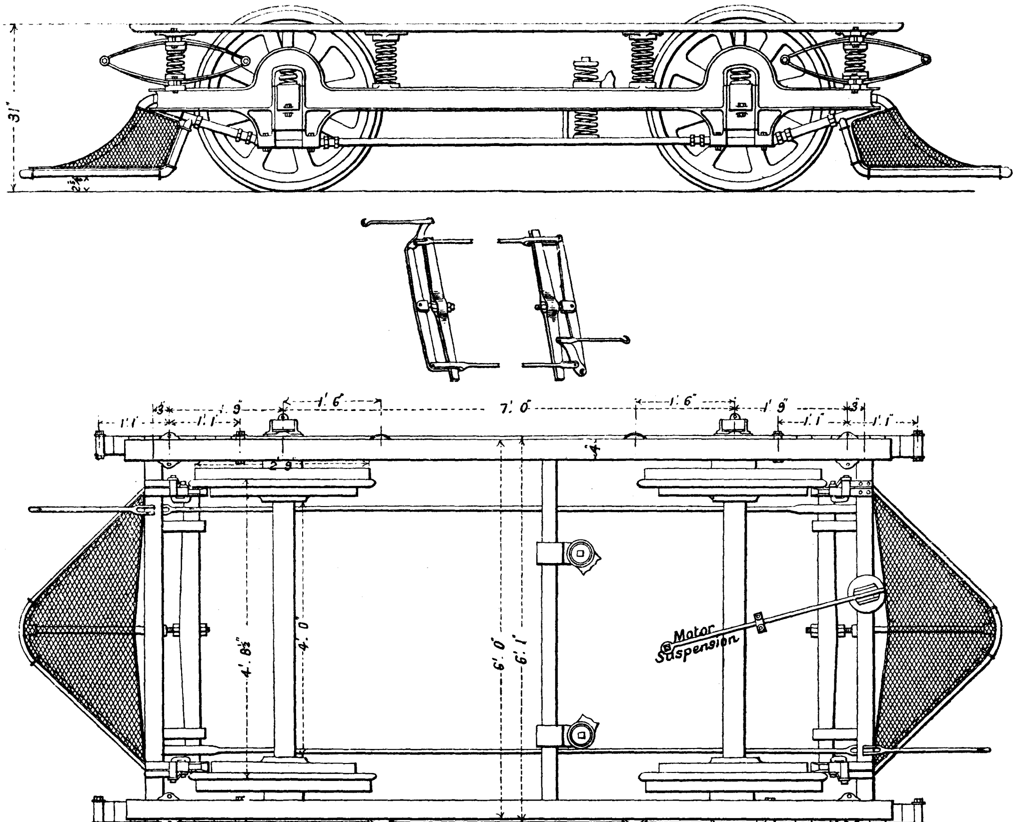


Fig. 206. "Imperial" Truck.

journal-boxes, and the car body is supported on the frame by a combination of coil and elliptic springs acting in the same way as those already described in the "Peckham" truck.

The "McGuire" Four-Wheel Truck resembles in many points the one just described. The side frames are made of solid pressed steel $\frac{3}{8}$ in. thick, flanged and bent into a **U**-shape. At either end the side frames are cross-connected by a **V**-piece riveted on to them. Side pieces are riveted to

the frame to fit on to the axle-boxes, as well as hollow yokes which hold the spiral coil springs which support the side frames on the axle-boxes. The car body is supported on a set of four spiral and four elliptical springs, placed in pairs at each end of the side frames.

A truck of this kind, fitted with motors by the Allgemeine Elektricitäts Gesellschaft, is shown in Fig. 207.

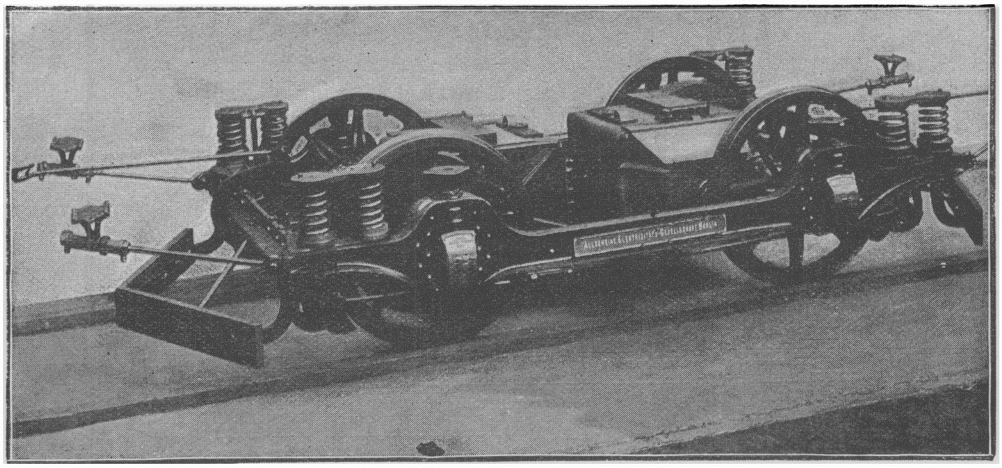


Fig. 207. "McGuire" Truck.

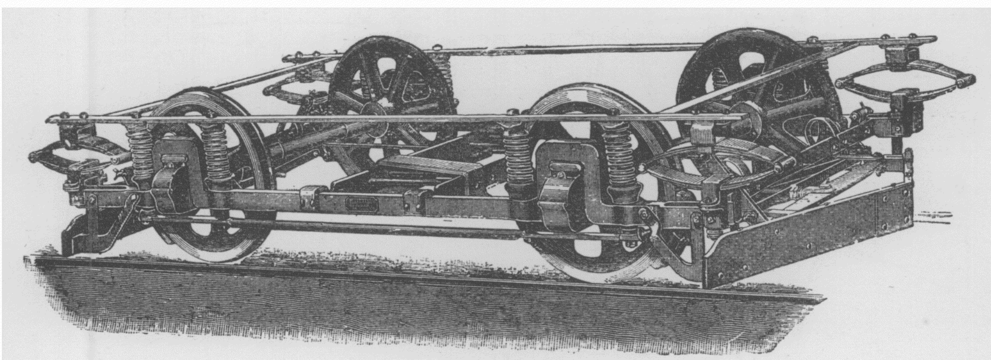


Fig. 208. "Brill" Truck.

Several other trucks, resembling the last two described, are manufactured. Fig. 208 shows a "Brill" truck. Elliptical and spiral springs are again used in combination, to act in a similar way as in the "Peckham" truck already described. The spring suspension from the axle-boxes is, however, absent in this truck.

We will now consider a different type of truck, namely, one with six wheels, and known generally as a "radial" truck. This was introduced to

do away with the waste of power due to the skidding and grinding of the wheels on curves of small radius which frequently occur on street railways. It originated in Boston, a city which is not laid out in square blocks like most American towns, but has winding streets. This truck is composed

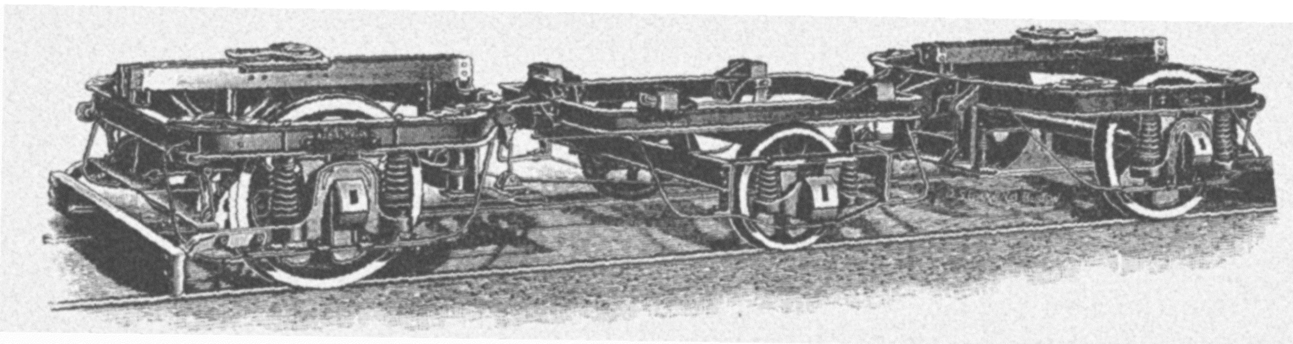


FIG. 209. "ROBINSON RADIAL" TRUCK.

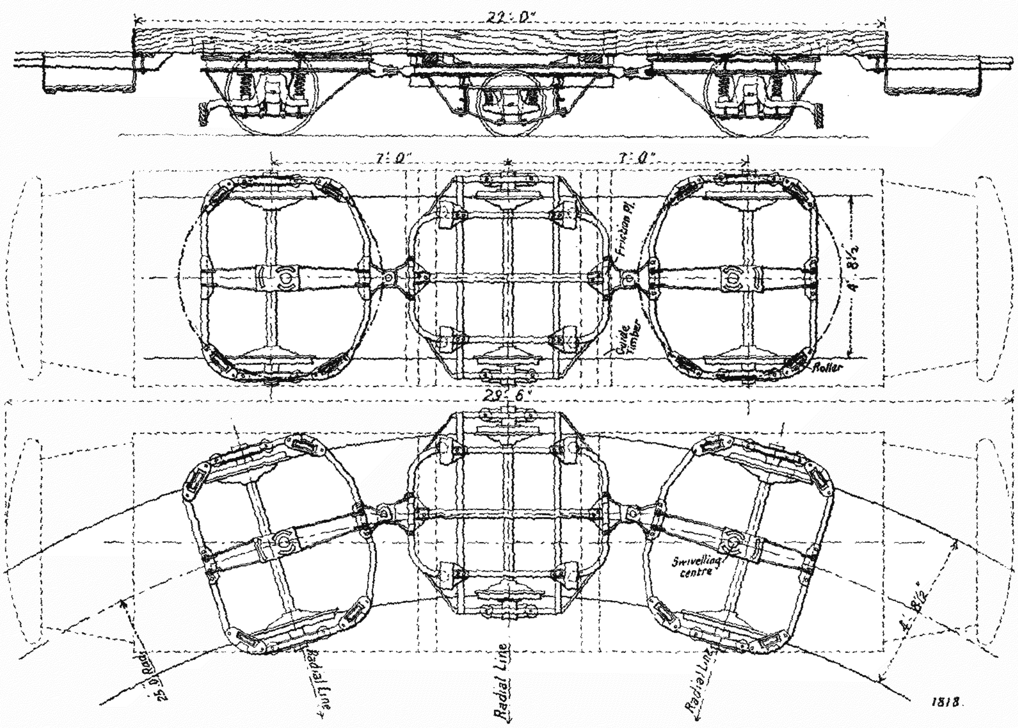


FIG. 210. "ROBINSON RADIAL" TRUCK. ELEVATION, PLAN, AND ACTION ON CURVE.

of three independent two-wheel trucks pivoted together, the two end trucks carrying most of the load and the motors.

The centre axle frame has smaller wheels, and moves transversely across the bottom of the car body, which is pivoted on the central truck

and not attached to it. In running, the axles become exactly radial in the curves. The framework of the trucks is built of steel channel-irons riveted together, and these are suspended by coil springs from the axle-boxes. Figs. 209 and 210 show elevation and plans of a radial truck and its behaviour on curves. The disadvantage of this gear is that on double curves of S-shape, the truck frequently derails, while it is more costly than a four-wheel truck. Where very large cars are in use, two four-wheel bogies are generally considered to be preferable to the radial truck.

Fig. 211 shows a typical American street car axle fitted to receive a 25 horse-power motor weighing approximately 2,000 lb., of which the axle has to bear about half. Instead of turning down the axle upon a lathe to finish it and bring it to its desired dimensions, it is often "die drawn" instead. The bars, after being rolled from the ingots, are drawn down

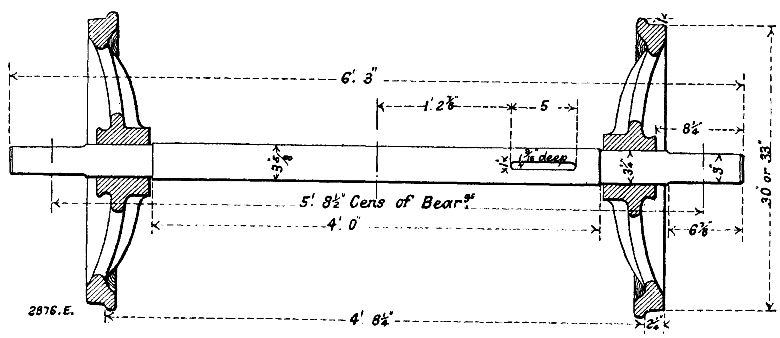


FIG. 211. MOTOR CAR AXLE.

through a die, as in the process of making wire; and it is claimed for the method that the torsional and transversal strength of the axles is increased, and sizes are guaranteed to be accurate to within a thousandth of an inch. As various keyways, collars, &c., are required to fit the motors on the axles, these are cylindrical in shape, it not being of much use, either in saving of weight or increased strength, to make them so as to have a form of greatest resistance. The cushioning of motors, truck, and car body from the axles is of great importance in increasing the life of axles. In constructing the journal-boxes to fit the axles, space should be arranged so as to allow approximately $\frac{1}{4}$ in. of side play to the axle.

The sides and ends of the brasses should be rounded off, so as to allow of good lubrication and to prevent the wearing of a collar on the axle. The journal-boxes, as now generally used on American street cars, have attained a very great pitch of perfection. Most of them are not looked

after or oiled for eight or twelve months together, and the brasses last six or eight years without renewals.

In comparing the modern electric motor truck with the old horse-car, it will be found that a notable strengthening of the axles has taken place, and that the journal-boxes are much modified. In horse-cars a load of as much as 500 lb. to the square inch of bearing surface of the journals was met with in recent practice. This has been brought down to from 300 lb. to 400 lb. per square inch, approximating more closely to railroad practice, where, on an average, 300 lb. per square inch is allowed. The increased weight and size of the car bodies also call for much stronger axles than are in use on horse-cars. (See Table L.)

TABLE L.—COMPARISON OF AXLES ON HORSE AND ELECTRIC CARS.

Style of Car.	Diameter of Axle between Wheels.	Diameter of Axles in Hubs of Wheels.	Journals.		Total Weight of Car Empty.	Depth of Key-way in Axle.	Seating Capacity.
			Diameter.	Length.			
	in.	in.	in.	in.	lb.	in.	
Four-wheel electric motor car	$3\frac{3}{8}$ to $3\frac{7}{8}$	3 to $3\frac{1}{4}$	$2\frac{7}{8}$ to $3\frac{1}{2}$	6 to $6\frac{1}{2}$	11,000 to 13,000	$\frac{1}{2}$ to $\frac{3}{8}$	30 to 50
Four-wheeled two-horse car .	$2\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{7}{8}$	$4\frac{3}{4}$	5,000 to 6,000	—	30 to 46

In both electric cars given above the gauge is 4 ft. $8\frac{1}{2}$ in., and 30 in. wheels are used.

Nearly all manufacturers build bogie trucks for use under cars of from 32 ft. to 40 ft. or 48 ft. in length over all, such as are used for inter-urban and suburban traffic more frequently than on city lines, where such long cars would be cumbrous and difficult to fill. In a future chapter the various types of cars used according to the nature of the service required will be more fully treated. America is the home and origin of the bogie, which has found there universal adoption on all the steam railroad cars.

Bogie trucks should only be used in cases where car bodies are too long to be supported on a four-wheel truck.

Take the weight of the car body to be 8,000 lb., the weight of the truck would be 4,500; and the motors complete, with the controllers and gears, would add 3,200 lb. more. This would give a weight on the track per wheel, of 3,925 lb. With the same weight of car body, and with bogie trucks weighing 3,000 lb. each, the motors being of the same weight, and it being necessary to mount both motors on one truck in order to get the best possible traction, we would have 2,550 lb. on each of the driving wheels of the bogie trucks. There is therefore a difference of 1,375 lb. per wheel between the single and double trucks, but this weight gives much

better traction, and while the difference apparently is in favour of the 8-wheel truck, it is really deficient in traction, and has an additional dead weight of 1,500 lb. per car to be hauled continually. While this weight may not be much on one car, it would amount to 30,000 lb. on a line operating 20 cars, and to propel 30,000 lb. dead weight requires current and coal. It therefore becomes merely a question of having a road-bed sufficiently heavy to stand the additional weight per wheel; and it must be remembered that fuel consumption cuts a very important figure in the operating expenses of any electric tramway.

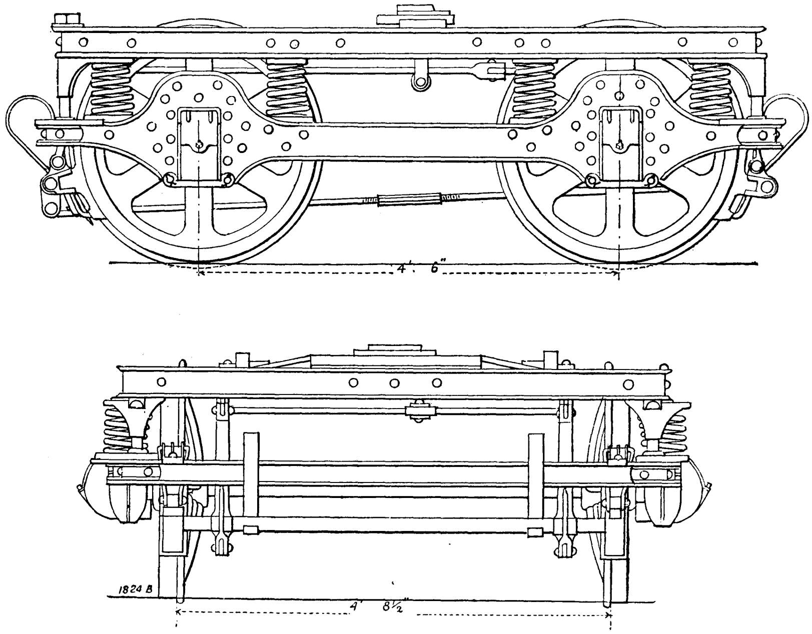


FIG. 212. "McGUIRE" BOGIE TRUCK.

For street railway work there are at present two distinct types of bogies in use: the ordinary four-wheel with the car-body pivoted on the centre of the truck, the load being equally divided between the wheels; and what is known under the name of the "Maximum Traction" truck. In the latter, the wheels of the bogie are of two different sizes, and the weight of the car is not equally divided, the greater part being taken by the larger wheels, while the smaller are but just enough loaded to keep the track. The object of this is to get the full benefit (as nearly as possible) of the weight of the car for adhesion in starting, as only one motor is used on each bogie, and the two pairs of wheels are not coupled.

This, of course, is only of importance when the line is hilly, or the tracks are unusually greasy. Under very adverse circumstances, the frictional

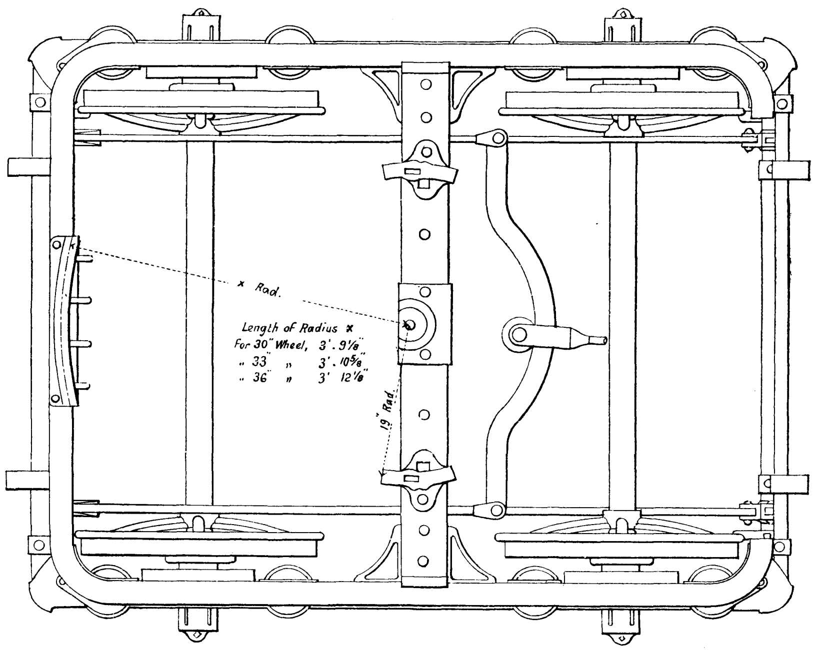


FIG. 213. "McGUIRE" BOGIE TRUCK.

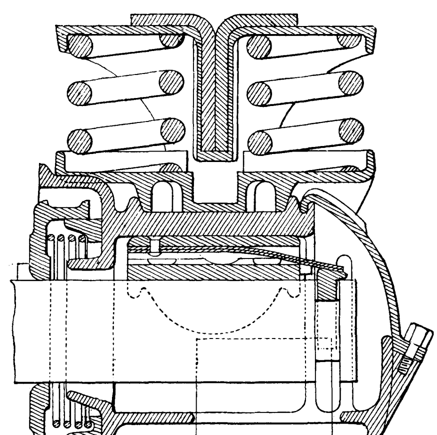


FIG. 214. "McGUIRE" JOURNAL BOX.

resistance between wheel and rail may fall as low as one-tenth of the total load on the wheel. If an ordinary bogie car weighs 8 tons, this would give 1 ton on each wheel; taking the horizontal starting effort as 70 lb.

per ton, 560 lb. would be wanted. The frictional resistance of the four wheels available, supposing the use of two motors, the axles not being coupled, would give 4 × 224 = 896, or amply sufficient. But the moment there are gradients, we find that under the unfavourable conditions supposed, the wheels would skid on a gradient of anything over one in 50. Under ordinarily favourable circumstances, or if sand were used, this would

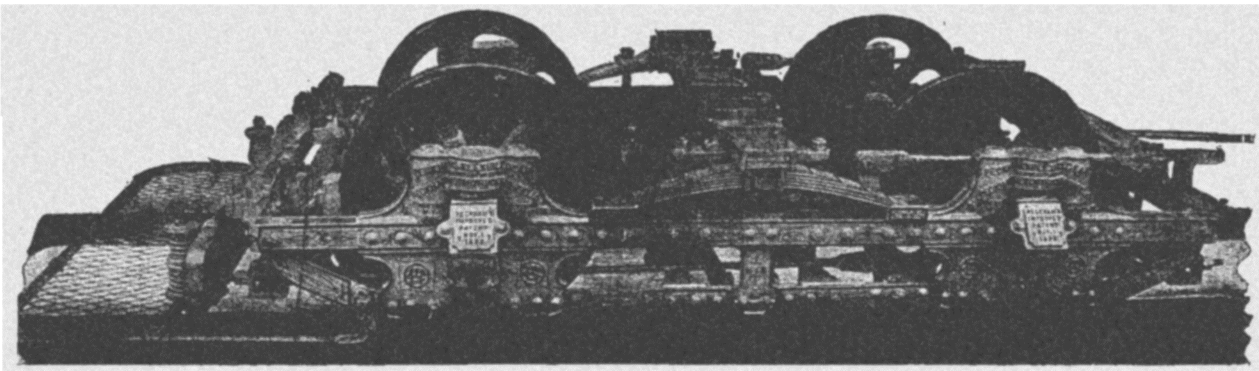


FIG. 215. "PECKHAM" BOGIE MOTOR TRUCK.

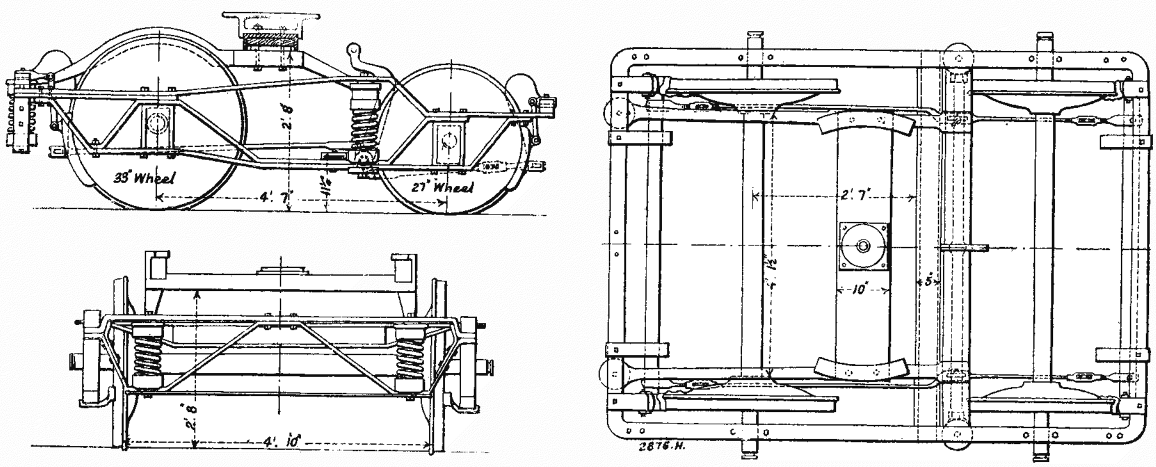


FIG. 216. "MAXIMUM TRACTION" BOGIE TRUCK.

not happen, as then a frictional resistance between the wheels and the rails of one quarter the load can be safely counted upon. For fairly level roads, therefore, where very long cars are required, the ordinary 4-wheel bogie fulfils all requirements.

Figs. 212 and 213 show the McGuire four-wheel bogie. It is similar in construction to the truck by the same maker already mentioned. Fig. 214 is a section through the journal, and is self-explanatory.

The Peckham four-wheel swivel bogie is in principle identical with the standard truck of the same name already described. Double spring suspension is provided, and coil and elliptical springs are used in combination. Fig. 215.

TABLE LI.—WEIGHTS OF MOTOR TRUCKS.

Make of Truck.	Weight of Wheel.	Diameter of Wheel.	Gauge.	Weight of Truck (Bare).	Weight of Truck Equipped with							
					S.R.G. 30.		W.P. 30.		W.P. 50.		G.E. 800.	
					One Motor.	Two Motors.	One Motor.	Two Motors.	One Motor.	Two Motors.	One Motor.	Two Motors.
	lb.	in.	ft. in.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Bemis, four-wheel	250	30	4 8½	3,123	5,500	7,800	5,100	7,000	5,700	8,200	5,000	6,800
Brill, four-wheel	300	30	4 8½	3,500	5,800	8,100	5,400	7,300	6,000	8,500	5,300	7,100
McGuire, four-wheel	300	30	4 8½	3,000	5,300	7,600	4,900	6,800	5,500	8,000	4,800	6,600
Tripp, four-wheel	280	30	4 8½	3,600	5,900	8,200	5,500	7,400	6,100	8,600	5,400	6,900
Bemis, eight-wheel	300	30	4 8½	{3,120* each}	5,420	—	5,020	—	5,620	—	4,900	—
Brill (maximum)..	{300 200}	{30 22}	4 8½	{2,700* each}	5,000	—	4,600	—	5,200	—	4,500	—
Tripp, eight-wheel	280	30	4 8½	{3,200* each}	5,500	—	5,100	—	5,700	—	5,000	—
Robinson, radial..	{300 200}	{30 24}	4 8½	5,000	7,300	7,600	6,900	8,800	7,500	10,000	6,800	8,600
Peckham, four-wheel	300	30	4 8½	4,000	6,700	6,000	6,300	8,200	6,900	9,400	6,200	8,000
,, eight-wheel	300	30	4 8½	—	—	—	—	—	—	—	—	—

* There are two of these trucks per car, making the total weight of trucks per car twice the weight above given.

TABLE LII.—DIMENSION OF CARS.

Cars for Street Railway Service.

—	Length.	Seating Capacity.	Weight of Car Body.	Weight with 30 Horse-Power Truck.
	ft.		lb.	lb.
Closed car..	16	22	4,000 to 5,000	11,000 to 12,000
,, ...	28	40	6,980	19,400
Open car (8 bench)	24	40	3,500 to 4,500	10,500 to 11,500
,, (10 ,,)	30	50	6,400	19,000

Cars for Freight and Passenger Service.

—	Narrow Gauge.		Standard Gauge.	
	Weight.	Load.	Weight.	Load.
	lb.	lb.	lb.	lb.
Eight-wheel flat	6,500 to 8,500	20,000 to 30,000	16,000 to 20,000	26,000 to 40,000
Eight-wheel box	10,000 ,, 12,000	20,000 ,, 30,000	18,000 ,, 24,000	26,000 ,, 40,000
Four-wheel coal and ore ..	4,000 ,, 6,000	10,000 ,, 12,000	7,000 ,, 8,000	16,000 ,, 20,000
Passenger car	20,000 ,, 22,000	40 to 50 passengers.	30,000 ,, 40,000	50 to 60 passengers.

Fig. 216 shows a "Maximum Traction" truck. In this style of truck it is usual to employ from 30-in. to 36-in. driving wheels and 22-in. to 24-in. trailing wheels. The pivotal centre of the car body is frequently placed directly over the centre of the driving axle. A

pivot plate is dispensed with, and the car is supported on roller-bearing rub-plates on the outside upper frame of the truck, formed in the shape of arcs of circles having the pivotal point of the truck for their centres. By this means the driving wheels can be set up under the car, and the smaller wheels can radiate clear of the car body. The weight of a truck of this style varies between 2,000 lb. and 4,000 lb. Tables LI. and LII. are useful in showing the approximate weights and sizes of trucks with and without motor equipments, and of complete street cars, such as are now in current use throughout America. While motors have been very much reduced in weight lately, the tendency with regard to trucks is rather the reverse. Very light trucks cannot be stiff, and their use is a mistake both for the motor equipments and permanent way.

CHAPTER XII.

CAR CONSTRUCTION.

THE difference between American and European tramway cars is very great, much more room being allowed to passengers in American cars than is the case in Europe ; and it will be seen from a glance at the annexed Tables LIII., LIV., and LV., that the car bodies in general use in America are far heavier than those which have been used on this side hitherto. This may be accounted for to a great extent by the fact of the nearly general adoption of mechanical traction in America, and it is more than probable that mechanical traction will very much change for the better the cars in use on this side of the Atlantic. The style and size of car to be adopted depends, of course, to a great extent on the kind of service it has to fulfil. Thus, for a line passing through crowded streets, where passengers are constantly getting on and off, small cars with ample platform space would be preferable; while for a suburban service, where passengers are generally taken from one end of the line to the other, cars of a much larger capacity should be adopted. The seating capacity of the cars in use in America varies within very large limits, as shown in Table LIII. The top-seat car so much used in this country is scarcely known in America. This may be accounted for in various ways. The American climate is more settled than ours, and at the beginning of each day it is easy to decide whether the day will be fine or not, and the manager of a tramway knows whether to send out open or closed cars. In most parts of America the winters are so cold that sitting on top of a car would be impossible during that season, while in summer the heat is so great that some kind of awning becomes a necessity. In some parts of California the temperature varies within fairly large limits each day, and this has caused the adoption of a half closed and half open car, so that if at any time a cold wind should start up, the passengers can move from the open into the closed part.

Figs. 217 to 227 show a few of the types of cars used in America. Figs. 217 and 218 are extremely characteristic illustrations, and show

TABLE LIII.—Giving Sizes of Usual American Car Bodies.

Type of Car.	Length of Body.	Length Over All.	Length of Platforms.	Width Over Sills.	Width at Belt Rails.	Weight of Car Body.	Seating Capacity.	Height Inside Centre.	Remarks.
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	lb.		ft. in.	
Closed motor car	16 0	24 0	4 0	6 0	7 6	4,500	22	—	Standard-gauge four-wheel car.
,, trailer ,, ...	16 0	24 0	—	—	7 6	4,000	22	—	Ditto
Convertible closed or open motor car ..	16 7	23 0	—	—	7 8	4,600	24	—	Ditto
,, ,, open or closed trailer ,, ..	17 6	24 6	—	—	7 7	4,300	28	—	Ditto
Vestibule closed motor car	17 0	25 0	—	—	8 0	4,800	24	8 0	Ditto
Closed motor car	17 10	26 0	4 0	6 0	7 6	4,800	26	—	Ditto
Vestibule closed motor car	18 0	26 0	4 0	6 0	7 6	5,100	26	—	Ditto
Closed motor car	21 0	28 0	3 6	6 0	7 6	5,250	30	—	Ditto
Convertible open or closed trailer car ..	22 0	29 0	—	—	8 0	5,000	36	—	Ditto
Open motor car	14 4	21 0	3 4	—	7 6	3,000	24	—	5 ft. 2 in. gauge four-wheel car.
,, ,, ...	—	22 6	—	6 0	6 10	3,500	35	—	Standard-gauge four-wheel car.
,, trailer car	—	23 0	—	6 0	6 10	3,400	35	—	Ditto
Vestibule open motor car	—	26 2	—	6 0	6 10	4,250	40	—	Ditto
,, ,, trailer car..	—	25 0	—	6 0	7 6	4,000	50	—	Ditto
Closed top seat motor car	15 10	26 0	—	6 0	7 6	5,000	44	—	Ditto
,, ,, trailer car	15 10	26 0	—	6 0	7 6	4,000	44	—	Ditto
Open ,, motor car *a*	—	24 8	—	6 0	6 10	4,400	59	—	Ditto
,, ,, trailer car *b*	—	24 9	—	6 0	6 10	4,400	59	—	Ditto
Combination open and closed top seat car *c*	—	27 6	—	6 0	6 10	4,600	48	8 1½	Ditto
Funeral motor car	13 10	20 0	—	6 0	7 0	3,900	—	—	Ditto
Street sprinkling motor car *d*	—	12 0	—	—	6 6	3,500	—	—	Standard-gauge eight-wheel car.
Closed trail car	22 0	28 10	—	6 0	7 6	6,000	30	—	Ditto
,, motor car	25 0	33 0	4 0	6 0	7 6	5,850	36	—	Ditto
,, vestibule motor car	25 0	33 0	4 0	6 0	7 6	6,050	36	—	Ditto
Convertible open or closed car	27 6	34 0	—	—	8 0	6,200	44	—	Ditto
Combination open or closed car *e* ..	—	29 0	—	6 4	7 6	5,500	40	—	Ditto
Open motor car	—	30 9	—	6 4	7 2	5,000	50	—	Ditto
,, ,, ...	—	34 0	—	6 4	7 2	6,000	60	—	Ditto
,, trail car	23 6	27 6	4 0	—	7 6	5,100	32	—	Ditto
,, ,, ...	—	34 0	—	—	7 6	6,500	70	—	Ditto
,, motor car	37 4	44 0	—	—	8 0	9,000	90	—	Ditto
Closed motor car, passenger and luggage combined *f*	26 0	32 0	3 0	6 10	7 6	5,850	24	—	Ditto
Closed top seat motor car	25 6	35 0	3 0	6 9	7 6	7,500	72	—	Ditto
Open top seat motor car	27 0	36 0	—	—	7 6	10,000	90	—	Ditto

a Height to top of awning, 15 ft. 3 in. *b* Height to top of awning, 15 ft. 3 in. *c* Length of closed body, 9 ft. *d* Capacity 750 gallons. *e* Length of closed part, 11 ft. 8 in. *f* Length of luggage compartment, 8 ft. 8 in.

TABLE LIV.—Giving Dimensions of Some English Car Bodies.

Style of Car.	Length of Body.	Length Over All.	Width at Widest Part.	Height Inside Centre.	Seating Capacity.	Gauge.	Weight of Car Body.	Remarks.
	ft. in.	ft. in.	ft. in.	ft. in.			lb.	
Two-horse car	16 1½	25 2	6 6	7 4	46	Standard.	3,800	Four-wheel.
,, ,, ...	14 9	23 9	6 3	6 7	48	,,	4,000	,,
,, ,, ...	14 9	22 3	6 6¾	6 10	48	,,	4,000	,,
,, ,, ...	12 2½	21 3	6 6	7 4	34	,,	3,000	,,
,, ,, ...	13 4	20 10	6 3	6 7	36	4 ft.	3,000	,,
One-horse closed car	14 0	20 0	6 7	—	18	Standard.	2,400	,,
Steam trailer double-decked car	20 0¼	29 1½	3 9	7 0	60	3 ft. 6 in.	5,900	Eight-wheel bogie car.

TABLE LV.—Showing Weight and Sizes of American Horse-Car Bodies.

Style of Car.	Length of Body.	Length Over All.	Width at Widest Part.	Height Inside Centre.	Seating Capacity.	Weight of Car Body.	Remarks.
	ft. in.	ft. in.	ft. in.	ft. in.		lb.	
One-horse "bobtail" car, closed ..	8 0	11 0	6 6	7 0	10	1,260	No conductor, no rear platform.
,, car, closed	12 0	17 6	6 6	7 6	16	2,330	With conductor, and two platforms.
Two-horse ,, ...	14 0	20 0	7 0	7 5	18	2,800	
,, ,, ...	17 8	24 6	7 6	7 6	28	3,900	
,, top-seat car, closed	14 6	24 6	6 6	7 4	40	3,800	
One-horse open car	—	12 6	6 6	6 10	20	1,900	
Two ,, ...	18 0	24 10	7 6	—	32	4,000	
,, ,, ...	—	25 0	7 6	7 0	50	3,450	
,, ,, top-seat car	—	24 9	6 8½	7 8½	59	4,100	

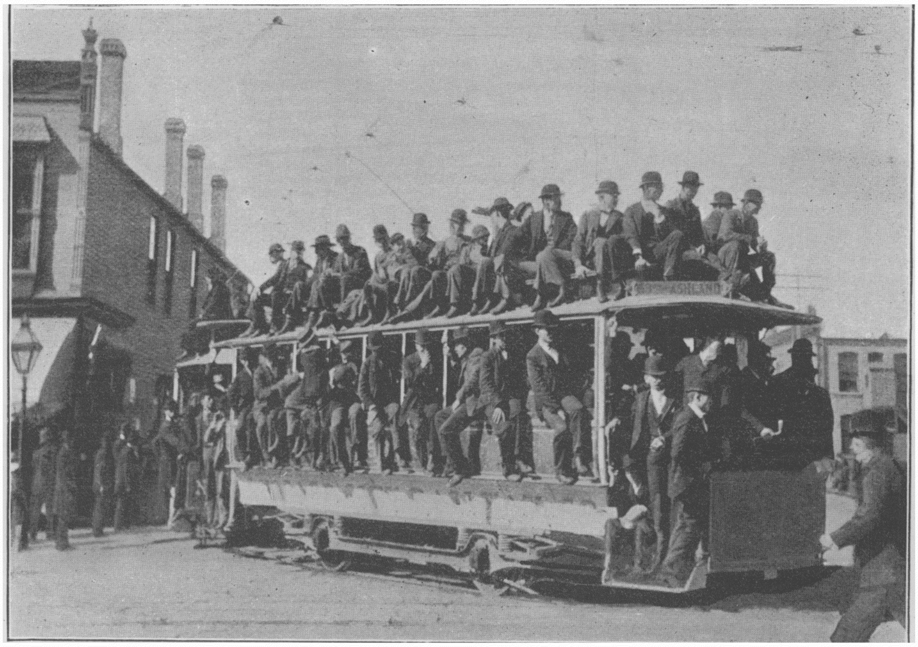


FIG. 217. CABLE CAR AT CHICAGO DURING THE WORLD'S FAIR.

FIG. 218. TRAIN OF CABLE CARS AT CHICAGO, "CHICAGO DAY," WORLD'S FAIR.

to what an extent overcrowding is not only possible, but is freely allowed on American cars. It must not be supposed, however, that street cars

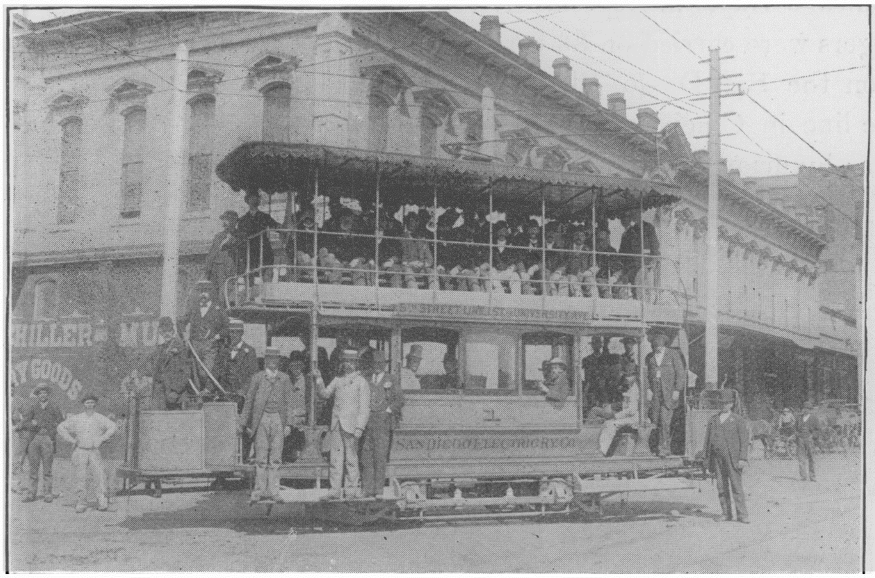


FIG. 219. "COMBINATION" OPEN AND CLOSED CAR, SAN DIEGO ELECTRIC RAILWAY, CALIFORNIA.

FIG. 220. CINCINNATI ELECTRIC CAR.

are habitually so overcrowded, while passengers are rigidly prohibited from climbing to the roof. In Chicago, however, during 1893, all rules were

set on one side, especially on special days at the Exhibition. Fig. 217 shows a single car, and Fig. 218 a train of electric cars as they were loaded on "Chicago Day," in September, 1893. On that day more than 208,000 passengers were carried on 83 cars. Fig. 219 illustrates a car with outside seats on the San Diego Electric Railway, and Fig. 220 is a car on an electric line in Cincinnati.

The luxurious fittings which are being introduced on all our railways

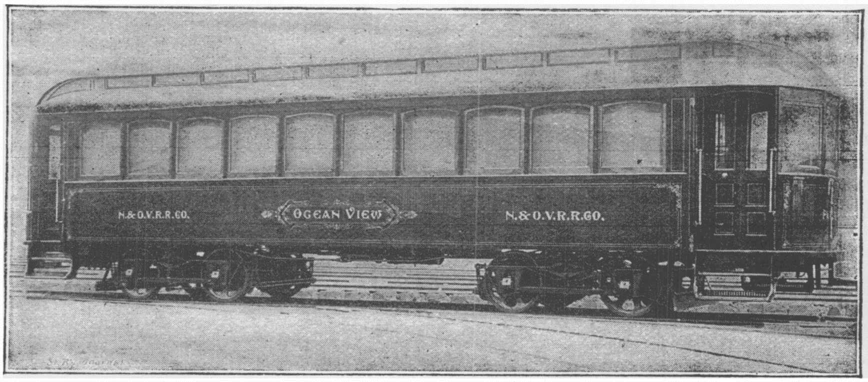


Fig. 221. Vestibuled Electric Railway Car, with Bogie Trucks.

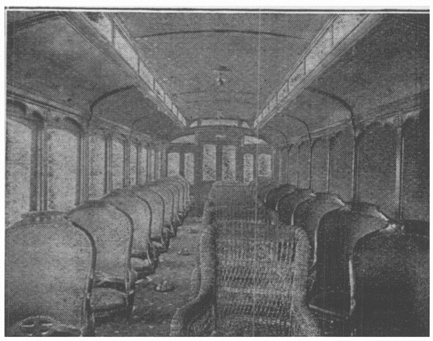


Fig. 222. Interior of Car shown in Fig. 221.

show the tendency of these companies to fulfil the demands of the travelling public. This has been realised by the street railway managers, and the inside of an American street car is as richly ornamented, upholstered, and lighted as the finest drawing-room cars running on our best railway systems.

The closed vestibule car, shown in Fig. 221 and Fig. 222, is very substantially built, and weighs, empty (with complete motor equipment), about 20,000 lb.

The ceiling is bird's-eye maple with gold decorations. The interior finish is mahogany, with brass trimmings. The fourteen windows are plate glass, and furnished with roller curtains. The ventilators are frosted glass, except those which indicate the route of the cars, which are cardinal

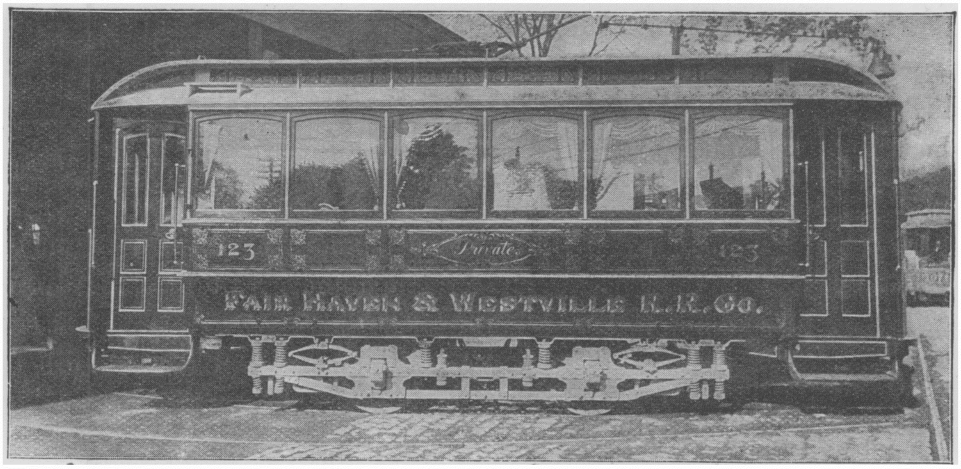


FIG. 223. ELECTRIC CAR WITH VESTIBULED PLATFORMS AND "EXTRA LONG" PECKHAM TRUCK.

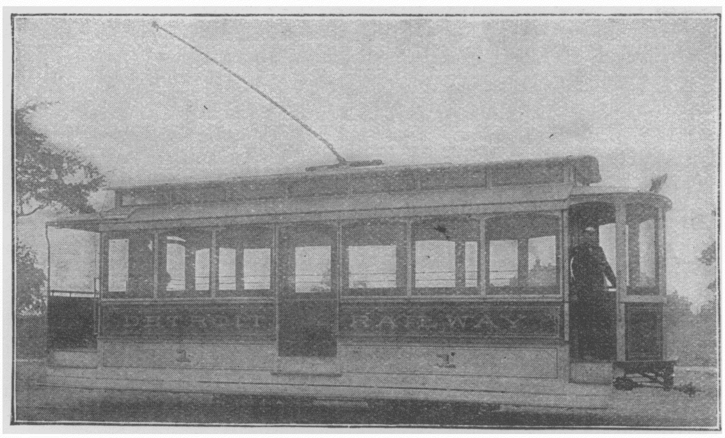


FIG. 224. ELECTRIC CAR WITH VESTIBULED FRONT PLATFORM AND SIDE DOOR.

in colour, and bear the name of the route. The seats are of rattan over springs, and are most comfortable and popular. The doors are double, and open from the centre, giving ingress and egress.

Fig. 223 shows a smaller vestibule car.

Fig. 224 shows a car having cross seats, with side aisle and

three doors, all of which are on the same side of the car. This permits passengers to be taken up and set down quickly. By removing the windows the cars can be operated as open cars in summer, so that the same rolling stock is available for both summer and winter service. The length over all is 31 ft., and that of the car body 22 ft., giving $4\frac{1}{2}$ ft. platforms. Upon the back of each seat is a push button, connected with battery and bell on the rear platform, so that any passenger can signal the conductor to stop. The central door can be opened and closed by the conductor from the back platform by means of a lever.

Fig. 225 shows an American type of top-seat car, heavily loaded.

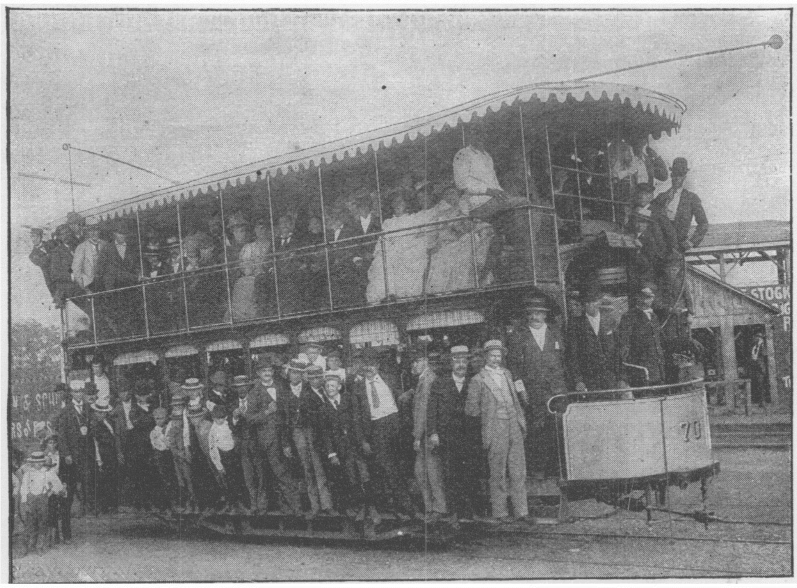


FIG. 225. AMERICAN ROOF-SEAT TROLLEY CAR WITH HEAVY LOAD, PECKHAM CANTILEVER TRUCK.

Figs. 226 and 227 show the standard closed and open cars of the Philadelphia electric lines. These may be taken as typical of the best American equipment.

It is impossible in this work to go into the art of car building. It is fully treated in Mr. C. B. Fairchild's able work on street railways, published by the New York Street Railway Publishing Company.

The electric motor car body has in some particulars to be constructed specially. Its framework must be exceptionally strong, and the cross timbers of the bottom frame must be so arranged as not to interfere with the motors, and to enable trap doors to be placed in such a way that the

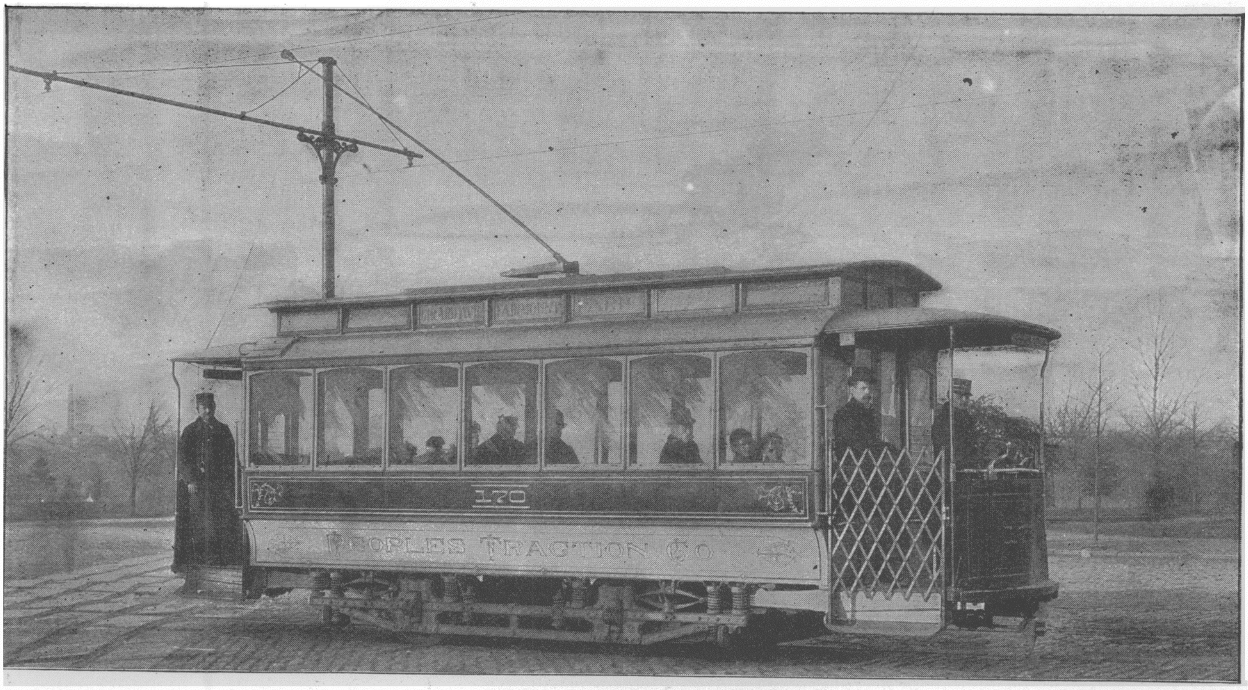


FIG. 226. STANDARD CLOSED ELECTRIC CAR, PHILADELPHIA. PECKHAM TRUCK, FOLDING SAFETY GATES, AND ANDERSON PIVOTAL TROLLEY.

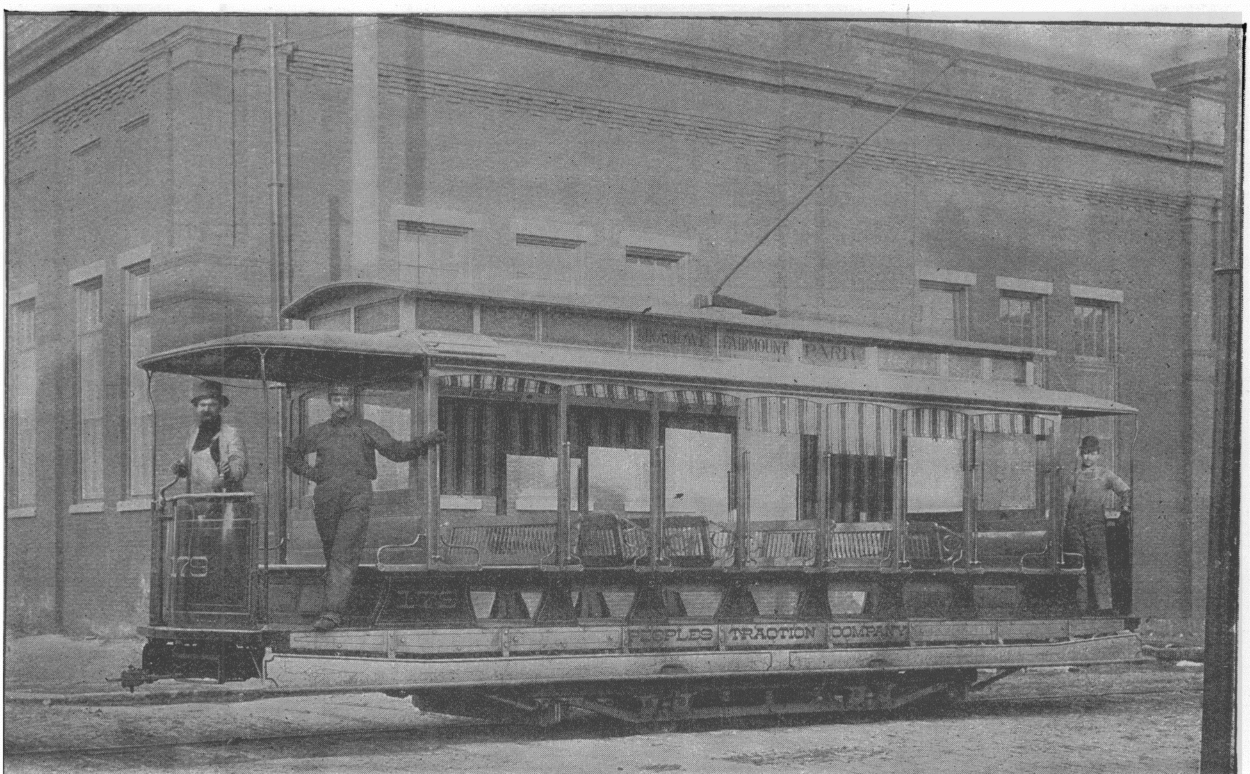
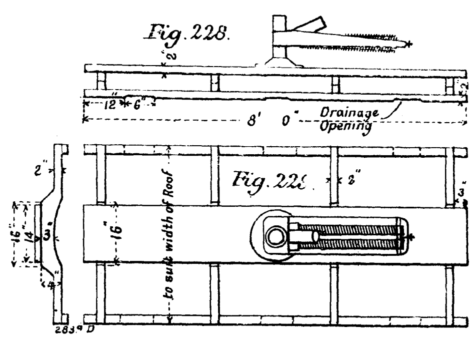


FIG. 227. STANDARD OPEN ELECTRIC CAR, PHILADELPHIA. PECKHAM TRUCK AND ANDERSON PIVOTAL TROLLEY.

whole or part of the motor can be removed through them without having to lift the car body off the truck. The roof of an electric car has also to be constructed with a view to great strength, so as to be able to support the trolley and its stand. Figs. 228 and 229 show the framework by means of which the trolley is fixed to the roof of closed cars. Besides the actual weight of the trolley, the increased speed and lurching, and the leverage exerted on the base of the trolley, due to the pressure of the trolley wheel against the overhead wire, requires the top frame of an electric car to be far stronger and heavier than on either horse, cable, or steam cars.

The woods principally used by American car builders are ash, white and yellow pine, hickory, cedar, cherry, cypress, oak, maple, sycamore, mahogany, satinwood, and teak. The American street cars are never



FRAMEWORK OF TROLLEY.

made hideous by the outside advertisements which we see in this country on our omnibuses and tramcars. Advertising is done, if done at all, by means of small metal or glass plates inside the roof of the car or on the windows. The painstaking care devoted to painting and varnishing street cars in America is very great, and the appearance of an electric or cable car is more like that of a private conveyance than of the tramway car that we are accustomed to see. The most elaborate design and ornamentation is used on first-class roads in painting the name on the cars of the street railway company which owns them, and the destinations for which the cars are bound.

CAR HEATING.—The cold winters which prevail throughout a great part of America, and the general use made of street cars, render heating of some kind a necessity. The old device, which is still in use to a very large extent, consists of small stoves, burning hard coal or coke. One of

these stoves is often fixed on the seat of a car, occupying the space of one passenger. The inconvenience of the system is evident, as while one person is much too hot, another is too cold. A good car stove, using coal, can be purchased and put up for about £4, and maintained at about 25 per cent. of the original cost. Such a stove burns about 35 lb. of anthracite a day. It has been estimated that the cost of heating cars by this means amounts to about 8d. per day of 18 hours. These stoves are, of course, a source of danger from fire if not carefully attended to, both during the day and before leaving the cars at night. Gas and oil stoves have also been tried. Besides these direct methods of heating, steam and hot water are also used to some extent. Both these indirect systems entail loss of time in refilling water or steam receptacles. The direct mode of transforming electricity into heat is now largely employed. This would seem to be the ideal method, were it not for the fact that it is not as economical as might be wished. In a comparatively mild climate like ours, the cost of electric heating would probably not be greater than that of heating by any other means. This is due to ease in regulating the heat, and turning it on and off at will. As great a radiating surface as possible should be given to the heaters, and they should be placed low down and near the doors of the car. The following Table gives the results of tests made by the Atlantic Avenue Electric Railway Company, of Brooklyn in the early part of 1894.

TABLE LVI.—Showing Electric Power Consumed in Heating Electric Cars.

Cars.			Temperature.		Electrical Power Consumed.
Doors.	Windows.	Contents.	Outside.	Average in Car.	
		cub. ft.	deg. Fahr.	deg. Fahr.	watts
2	12	850½	28	55	2,295
2	12	850½	7	39	2,325
2	12	808½	28	49	2,180
2	12	913½	35	52	2,745
4	16	1,012	7	46	3,038
4	16	1,012	28	54	3,160

Taking into account that the electric current need not be used continuously in the heaters, probably only one-third of the amount of power given in the above Table would be necessary on an average during the

day. Supposing the cost per Board of Trade unit to be $1\frac{1}{2}$d., the cost of heating on the line above mentioned would in all probability be less than 1d. an hour per car. For our climate this would be much reduced. The cost of electric heaters is far greater than for coal consuming stoves, probably averaging about 8 lb. per car. Depreciation is a fairly heavy item, but less than with coal fires, probably under 20 per cent. It must be remembered, however, that a large amount of labour is saved, and that seating space is not lost. The heating of the cars is also much more uniform.

TABLE LVII.—Showing Cost of Electric Car Heating on Chicago City Railway Company Cars. Working Time, 18 Hours per Day.

	d.
Interest on original cost at 6 per cent.	0.41
Depreciation at 10 per cent.	0.69
Repairs and maintenance	0.10
Cost of power	46.80
Total	48.00, or 4s.

The cars on which these tests were made were 21 ft. long. Cars were heated 35 deg. Fahr. above outside temperature. Cost of coal was 5s. 6d. per ton; the current used in the electric heaters, 6.2 amp.; the average voltage, 500 volts. It must not be forgotten that the heaters were practically always in operation, the winter being a very cold one.

Lighting.—Lighting is another item to which Americans pay great attention in their street cars. The cable cars are nearly universally lighted by the Pintsch gas system, or by very large petroleum lamps. The electric cars are, of course, lighted by electricity, usually by five or ten 16 candle-power lamps, taking their current from the trolley line. The head lights still burn oil, so as to guarantee their not going out if anything should happen to the electric supply. In many cases, however, an electric head light is furnished as well.

Watering Cars.—In America, watering cars are usually provided with motors, and run between the ordinary passenger cars. At Toronto, Canada, the local authorities have made a contract with the Street Railway Company to water all the streets through which their lines run. The capacity of these tank cars is very great, and the watering is done much better and more rapidly than if the ordinary watering carts drawn by horses were used.

Snow Sweepers.—The removal of snow from the tracks of a street

railway is of the greatest importance in a country where heavy falls of snow are a rule. The ordinary methods of sweeping and carting away falls of snow adopted in this country would be of no practical use. For cleaning tracks after a heavy snowfall, specially-built snow sweepers have been developed. Two types of these are generally used. The first, of which an example is shown in Fig. 230, is used on country roads or extremely wide thoroughfares. It consists of an extra heavy truck, carrying two large circular wire brooms, set on a slant on either side of the car. A

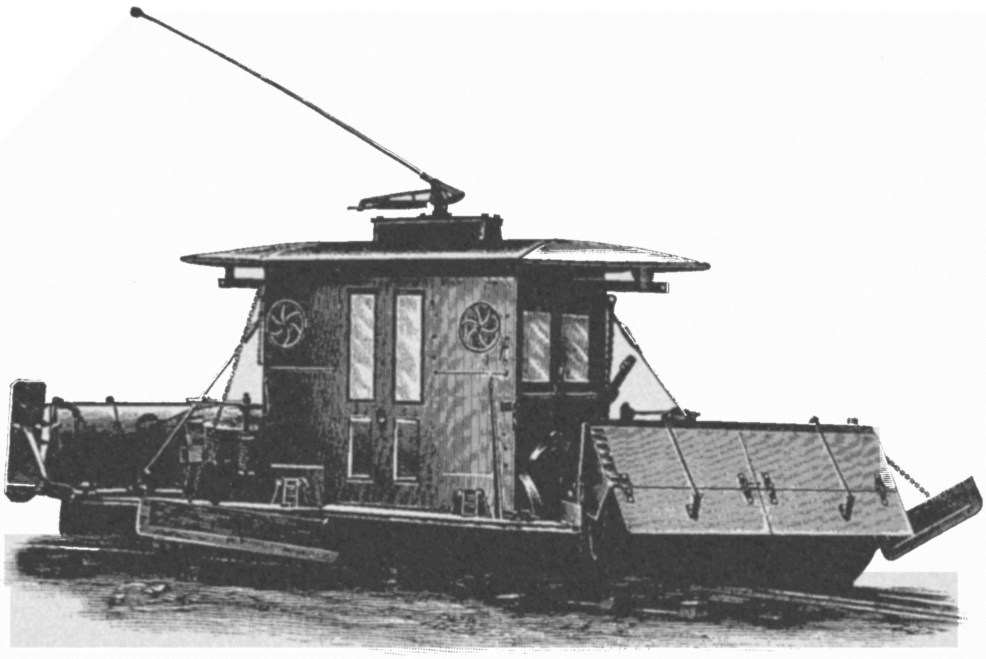


FIG. 230. ELECTRIC SNOW SWEEPER.

50 horse-power motor is used to drive the brooms, and, besides this motor, the car is furnished with the usual pair of 25 horse-power motors to drive the car itself along the road. Behind the brooms the ordinary snow-scrapers are usually provided.

For cities having crowded streets, and where large accumulations of snow are never permitted to remain in the streets, a different kind of snow plough is used. This consists simply of an extremely heavy car, furnished with a pair of powerful motors driving it, and provided with scrapers, which scrape the snow from the centre of the track and deposit it on each side. With such an apparatus it is not possible to remove more than 2 in. or 3 in. of snow at a time.

Freight Cars.—On many electric street railways in America a regular parcels service exists, for which special freight cars are provided, which run at certain intervals between the ordinary passenger cars. Fig. 231 represents such a car as is used on the Rockland and Camden Street Railway. The car body is 25 ft. long, 7 ft. wide, and is mounted on two four-wheel bogies. A 25 horse-power motor drives each axle by means of a single reduction gearing. The car complete weighs 13 tons, and carries a load of 10 tons. The powerful motor equipment with which this car is

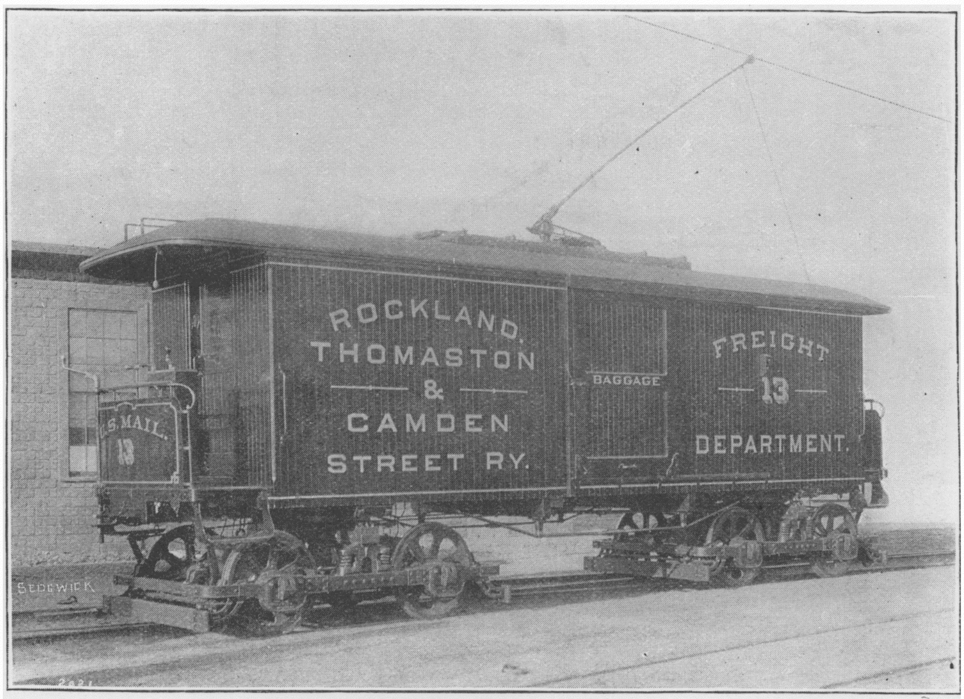


Fig. 231. Electric Street Railway Goods Car.

provided is accounted for by the fact that several long gradients of 1 in 13 are encountered on the road over which it runs.

Fig. 232 is a plan of the car body which is used on the Brooklyn Electric Street Railway for conveying mails from the head post-office to the various district offices. There are at the present a great number of electric lines on which postal cars are running. In a future chapter it is intended to treat more in detail the advantages of such a system from the street railway manager's point of view. One half of the car is used as a smoking compartment.

Specification for Electric Car.—Some idea of the care taken in the construction and finish of American street cars may be gained from the following specification of a closed electric motor car body.

SPECIFICATION FOR CLOSED MOTOR CAR BODY.

Dimensions of Car Body.—Length of car body over end panels at sill, 18 ft. Length of car body over platform crown pieces, 26 ft. Width of car at sill, including panels, 6 ft. 2 in. Width of car body at belt rail, 7 ft. 6 in. Height inside centre, 7 ft. 8 in. Height of car from underside of sill to top of trolley board, 8 ft. 6 in.

Doors.—Double doors so arranged that motion imparted to one will transmit it simultaneously to the other.

Windows.—Six windows on a side. Shape of window heads, Gothic.

Platform.—Length of platforms, 4 ft., either with opening and step at both sides, or with dasher extending around one side, leaving but one step opening at right-hand side, facing car. The dasher rail at left-hand side to be secured to the car body; the dasher to be of No. 16 sheet steel, 2 ft. 6 in. high.

Bottom Framing.—Side sills, of oak, $3\frac{3}{4}$ in. by $5\frac{1}{2}$ in. End sills, of oak, $3\frac{3}{4}$ in. by $4\frac{1}{2}$ in. Centre cross-joists, of oak, $3\frac{1}{4}$ in. by 8 in. Intermediate cross-joists, $2\frac{3}{4}$ in. by $4\frac{1}{2}$ in.

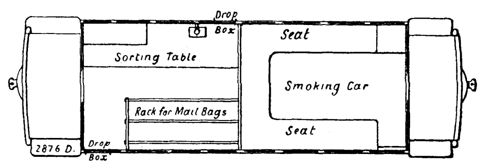


Fig. 232. Combination Mail and Smoking Car.

Framing to be done in the most substantial manner; all mortices and tenons to be thoroughly white-leaded, and driven together and secured by tie-rods of refined iron.

Floor.—Framing to be arranged with trapdoors to suit requirements of the electric motors. Floor boards to be of $\frac{7}{8}$ in. by $3\frac{1}{4}$ in. yellow pine, dressed on both sides, securely fastened to body framing with wire nails. Floors will be fitted with ash tapered floor mat strips screwed to floor; dimensions, $\frac{5}{8}$ in. at top and $\frac{3}{4}$ in. at bottom, reaching the entire length of car floor, excepting a space of 2 in. at end to allow for sweeping.

Trapdoors.—The trapdoors will be made to suit specified electric motors, will be framed of ash, framework 1 in. by 3 in., tenoned, mortised, and dowelled.

Body Framing.—Corner posts $3\frac{1}{2}$ in. thick. Side posts $1\frac{3}{4}$ in. thick. Sweep of posts 8 in. Belt rail $1\frac{9}{16}$ in. by $4\frac{1}{4}$ in. Top rail $1\frac{3}{4}$ in. by $2\frac{3}{4}$ in. Lower ventilator rail $1\frac{3}{4}$ in. by $3\frac{1}{8}$ in. Upper ventilator rail 1 in. by $2\frac{1}{4}$ in. All body framing to be of straight-grained white ash, free from sap and shakes, thoroughly dry and well seasoned. All joints white-leaded and all tenons pinned. Posts to be mortised into sills, and shoulders boxed $\frac{1}{4}$ in. into sills and fastened with strap bolts. On concave panels there will be four ash ribs of tough ash between every two posts; dimensions of ribs, $\frac{5}{8}$ in. by $1\frac{3}{4}$ in. These will be mortised into sills and fastened on concave rails securely with screws. The centre panel ribs are of same dimensions as above, and are mortised into belt and concave rails, draw bored and pinned. The belt rail is grooved to receive the panel, and is not nailed along the upper edge. The side belt rail is dovetailed into posts, no wedges being used. All panels to be heated before being placed in

position and glued to posts, ribs and rails being nailed only at the posts; panels backed with a good quality burlap securely glued in place. After glue is thoroughly hardened, the burlap will be painted one heavy coat of mineral paint. Truss rods of double refined iron, of suitable size and placed underneath seats, extending entire length of body.

Roof.—The roof to be monitor deck pattern, full length of car body, with eight ventilator sashes on each side and three transom lights at each end, the centre transom to be pivoted. Roof to be strengthened with four concealed steel rafters, $\frac{5}{8}$ in. by 1 in. These rafters are to be placed in the roof so as to relieve to the best advantage the strain of the trolley apparatus, and are forged to the shape of the roof in a solid piece with **T** at each end, by which they are fastened to top rail with wood screws. Roof painted with thick white lead, and all nail holes screw holes, and joints puttied, and covered with No. 6 cotton duck well laid in white lead and painted three coats.

Trolley Board.—Trolley board fitted on the outside made to suit the requirements of any specified trolley. The board to rest on ribs laid in white lead.

Hoods.—Hoods to be detachable, oak frames and ash carlines covered with $\frac{3}{8}$ in. tongued and grooved poplar boards $2\frac{1}{2}$ in. wide. The entire hood to be covered with No. 6 cotton duck, and treated in the same manner as rest of roof.

Dasher Posts.—End dasher posts extending from crown rail to underside of hood. The bottom of dasher-posts where they go through washer, crown piece and knees, to be tapered, so that when drawn down they wedge and always maintain the same position. Dasher caps of cherry wood extending full length of dasher.

Steps.—Malleable iron hangers with oak treads securely rodded on under side. Step to be provided with a back fender or riser, closing step opening, so as to prevent accidents to passengers by foot slipping through.

Brakes.—One brake shaft on each platform, to be $1\frac{1}{8}$ in. in diameter at the top, and $1\frac{3}{8}$ in. at the bottom, and provided with 12-in. ratchet brake handle of solid bronze metal.

Gates.—Gravity gates arranged to be set on the step, hinged to car body, so that when gate is folded up it swings inwardly towards the car body, and is latched thereto.

Buffer.—Buffer of oak 4 in deep by 6 in. wide by 25 in. long, faced with $\frac{1}{4}$-in. iron securely screwed in position. The buffer is to be fastened to crown piece with four $\frac{1}{2}$-in. bolts, and two centre platform knees to form an additional support for buffer by being brought out on the underside $4\frac{1}{2}$ in. from inner face and bolted with two $\frac{1}{2}$-in. button-headed bolts.

Couplers.—To be the Van Dorn automatic pattern.

Sand-Boxes.—Car to be fitted with two pedal sand-boxes placed at diagonal corners of car, and worked by levers extending to platform.

Gongs and Bells.—One 12-in. pedal alarm gong under each platform. Two signal bells with loose hammer attachment to prevent crystallisation of the gong, one bell under each hood. The bell cord to be $\frac{3}{8}$ in. round leather belting, and of sufficient length to reach the outer edge of hood.

Outside Trimmings.—Solid bronze metal trimmings outside. There are to be two body handles at each platform opening; one a curved bronze handle attached to the end belt rail, and the other handle attached vertically to the corner posts, and 30 in. in length.

Head Light.—One oil head light.

Lamps.—Two oil lamps in diagonal opposite corners. Car to be wired and fitted for five incandescent lights, three of which will be arranged under a central reflector, and one half-way between centre and doorway at each end of car.

Inside Finish.—To be what is known as No. 2 palace. The wood employed to be cherry including doors, linings, lamp-houses, and mouldings, and ceiling of three-ply veneer of birch, quartered oak or maple, decorated. Back of veneer ceiling, if used, to be painted before being

put in position. Hand poles of cherry and with grained leather hand straps double-riveted, with ornamental bronze metal trimmings. Mouldings for advertising cards to ceilings. Seats and backs of cherry slats covered with Wilton carpet. Space underneath seats to be closed with panel work extending from floor to underside of seat rails, with door in centre on each side with spring hinge at bottom, and provided with bronze catch; said panel work to be easily removable, with bronze wire screens for electric heaters. All mouldings to be of solid cherry, and the entire inside finish rubbed to a dead finish, or highly polished and first-class in all particulars.

Sash.—Sash to be of cherry $\frac{5}{8}$ in. thick, and glazed with double thick French glass set in felt and screwed in position by mouldings; the bottom of the sash, when lowered, to be protected from bruising by gum-cushions attached to foot of posts.

Blinds or Window Shades.—Spring roller curtains.

Painting.—All parts to be thoroughly primed with white lead, filled, puttied and surfaced until a perfectly smooth surface is obtained, and to receive from three to five coats of body colour, or until the surface is thoroughly covered. The style of ornamentation, colour, and lettering to be decided on shortly after the contract is awarded. Varnishing to be done in the best workmanlike manner, and the quality of varnish to be equal to the best American varnish.

Material and Workmanship.—The material and workmanship entering into the construction, finish, and painting of the car body to be performed in a thorough first-class and workmanlike manner. All rails and sills to be full length and without splicing. Mortises and tenons must fit each other tightly without false filling, and to be well white-leaded before driving together.

CHAPTER XIII.

CAR WHEELS AND BRAKES.

THE third and last, though by no means least important, part of a truck is the wheels. These are chilled cast iron, ferro-nickel, ferro-manganese, steel-tyred, and solid steel. Chilled iron is by far the most extensively employed, but there is a strong tendency, even in America, in favour of adopting better material for self-propelled cars. The chills used in America for casting wheels are, in some form or other, contracting chills, which contract on to the rim of the wheel directly the molten iron is in the mould, some contracting automatically by the effect of the heat on the chill, others being forced on to the wheel by externally controlled means.

This causes the depth of the chill to increase, and makes the chilled surface more uniform. The chill generally penetrates about $\frac{3}{4}$ in. into the rim of the wheel. As soon as the castings are sufficiently set, they are removed from the chills and placed in annealing furnaces, where they are cooled down gradually, the process lasting four days or so. This prevents unequal contraction and breaking of wheels. After they have cooled down they are finished off, if they require it, by means of emery wheels, as no other tools would work them, owing to the hardness caused by the chill. The weight of horse-car wheels in America varies from 180 lb. to 200 lb.; for cable cars wheels of from 200 lb. to 250 lb. are used, and for electric cars the weights vary between 300 lb. and 425 lb. The diameters of the wheels most in use vary between 22 in. and 36 in. Table LVIII is useful to determine the speed of a car having various-sized wheels at a given number of revolutions of the motor. The special and most important conditions which wheels have to fulfil may be briefly stated as follows: Wheels broken must show clear grey iron, free from blowholes. The chill must not vary in depth more than $\frac{1}{4}$ in. from the standard depth specified all round the tread of the wheel. The wheel must have no flats, and be absolutely cylindrical. The tread and body of the wheel must be smooth and free from sand, slag or blowholes, or deep and irregular wrinkles.

TABLE LVIII.—REVOLUTIONS PER MINUTE OF VARIOUS-SIZED WHEELS TO MAKE VARIOUS SPEEDS.

Diameter of Wheel.	Miles per Hour.									
	2	4	6	8	10	15	20	25	30	40
in.										
24	28	56	84	112	140	210	280	350	420	560
26	26	52	78	103	129	194	258	323	388	517
28	24	48	72	96	120	180	240	300	360	480
30	22	45	67	90	112	168	224	280	336	448
33	20	41	61	82	102	153	204	255	306	408
36	19	37	56	75	93	140	187	234	280	374
42	16	32	48	64	80	120	160	200	240	320

More than any other part of a street car, the wheels require to be strong, as they have to stand very rough usage. Dearly-bought experience has proved conclusively that the section of the wheel must be designed to fit the section of the rail on which it has to run. This would seem self-evident, but in many cases has been disregarded with disastrous consequences. Very interesting papers on chilled steel car wheels were published in some recent issues of the American *Street Railway Journal*, and from them much of this information is derived. Considering the hardness of the chill, it seems extraordinary that the flanges should sometimes be ground down to odd shapes in a very short time, both in the hardest and softest wheels. Bad track, bad rails, bad forms and sizes of wheels and rails are responsible for this rapid wear. As well as on railroads, it has been found necessary on street railways to slightly cone the tread of the wheel, and in order that the wheels may remain on the rails it is necessary to provide them with a flange, which, to minimise friction, must have its side form a considerable angle with the side of the rail. In practice this angle varies between 20 and 35 degrees. Practice has shown that the depth of flange first used on street car wheels, which attained a maximum of $1\frac{1}{4}$ in., was a mistake, and at present flanges of from $\frac{1}{2}$ in. to $\frac{3}{4}$ in. deep are used. Owing to the use of the step rail, flanges in America are generally much thicker than in this country, where the grooved rail is universal.

It is necessary that the axles be perfectly parallel, and that the line connecting the centre of the journals be perpendicular to the axes of the axles. If these conditions are not filled, both track and wheels will suffer, and sharp flanges result.

The cast iron of which chilled wheels are made in America has some

remarkable properties. Tests of some of the best American car wheels have shown tensile strengths of from 35,000 lb. to 40,000 lb. per square inch; in fact, in many respects this cast iron presents more the qualities of mild cast steel or wrought iron than of cast iron. This cast iron is found to take impressions from blows of a hammer in exactly the same way that a piece of wrought iron would. Pieces of this iron have actually been hammered into plates. The life of chilled wheels is longer on steam railroads than on electric street railways, owing to the smoother track and smaller number of stoppages on the former. On railroads the mileage of a wheel often attains 100,000 miles, whereas on street railways 80,000 miles is a maximum figure occasionally reached. Flat wheels, caused by a bad use of the brake, are a source of much trouble, but can be avoided by careful handling of the brakes. Motor car drivers should be educated carefully in this regard. A small flat on a wheel of course encourages the formation of a larger, because when the brake is set the tendency of the wheel naturally is to stop on the flat already formed. Flats can be minimised by substituting steel-tyred or solid steel wheels for chilled iron, but the objection to their use is the higher price. A careful motor-man by judicious use of sand-box and brake, can often grind off small flats.

To insure a good quality of wheel, many American street railway companies require manufacturers to guarantee a minimum mileage. As it is often very difficult to keep the mileage run by each wheel, this guarantee is in most cases only a form. It would seem of great importance to keep accurate results of mileage. This is clearly evidenced by the tests which Mr. W. E. Partridge published in the *Street Railway Journal*, in which enormous differences between wheels of various makers have been found, graduating up from averages of 10,000 miles to 70,000 miles, and in some cases, to nearly 80,000 miles per wheel. This shows that no road can afford to buy anything but first-class wheels by recognised and reliable manufacturers. There is no test but that of actual practice which can determine whether wheels will last or not, and therefore every operator should carefully watch mileage results. On English roads chilled wheels have also been used successfully, the average mileage of a wheel often reaching 50,000 miles.

Steel-tyred wheels similar to those adopted on European railroads are in current use on many tramways on this side of the Atlantic, and it seems as if they might find adoption in America. Many American engineers are already in favour of steel-tyred wheels. For cast-iron chilled wheels

special iron is required, and the manufacture is by no means easy. Cast-steel wheels have been used to some extent, but their price is much higher and their advantages only slightly greater than those of the cheaper cast-iron chilled wheel. Wrought-iron wheels, with steel tyres, have proved very efficient on railroads. They are claimed to be more durable than chilled wheels, owing to their greater elasticity; but their great advantage seems to be that they admit of the use of interchangeable hardened steel tyres, and also that the steel tyres can be turned down if flats are formed. This type of wheel is also claimed to be much lighter. In this style of wheel the rim is rolled in a special form of rolling mill, the spokes are often elliptical in shape, and are cut into lengths as they come from the rolling mill. The hub is formed by forcing a piece of heated iron into a die. The different parts of the wheel are then assembled and heated in a special furnace to a white heat. It is then placed in a die, and a steam hammer is brought down on the die, thus causing the rim, spokes and hub to be firmly welded together. The wheel, when removed from the die, is cleaned, bored, and finished on the lathe, and is then ready to receive the steel tyre. It is claimed that the life which may be expected from steel tyres is 200,000 miles.

We will now examine some of the most important accessories of trucks, namely, brakes, sand-boxes, bells, safety fenders, steps and gates, car couplers, &c.; most of them present special features in design, which have been dictated by experience.

The greater speed of electric cars and the adaptation of electricity to light railway service, render the question of brakes most important. That this has been fully realised is proved by the numerous types lately developed for use on electric cars. Brakes may, for reference, be classified as follows:

Hand brakes $\left\{\begin{array}{l}\text{acting on rim of wheel.}\\ \text{acting on axle.}\end{array}\right.$
Air brakes.
Electric brakes.

The weight of street cars, on both cable and electric roads, has been greatly increased: from 4,000 lb. or 6,000 lb. to 12,000 lb. and 13,000 lb. The loads have not increased in the same proportion, but the loaded car, instead of being about 8,000 lb. or 10,000 lb. is now nearly 20,000 lb.

In horse-car days the speed was on an average six miles per hour. Cable cars regularly run six miles per hour in a busy street like Broadway, New York, and in streets where the traffic is less the cable is speeded to

eight and ten. Electric cars have higher speeds, and twelve, fifteen, and twenty miles per hour are common. Higher rates in the suburbs are maintained with ease.

The question of the momentum of the car, or the power required to stop, shows even more effectively the enormous difference between horse and power tramways. The horse-car, weighing 10,000 lb., and moving at a speed of six miles per hour, has a stored energy equal to 12,025 ft. lb.; or, to put it another way, the work of stopping, which has to be done by the brake shoe on the wheels, is equal to lifting six tons one foot high. The electric car, at twenty miles per hour, represents a force of 280,000 ft. lb., over twenty times as much (Table LIX).

TABLE LIX.—Giving Stored Energy of Car in Movement.

Horse-car	and	load	10,000	lb.,	6	miles	per	hour,	12,025 ft. lb.
"	"	"	10,000	"	8		"	"	23,000 "
"	"	"	10,000	"	10		"	"	33,000 "
Electric	"	"	20,000	"	15		"	"	150,000 "
"	"	"	20,000	"	20		"	"	278,000 "

With increased speed, the distance from the car to the point where danger of collision becomes imminent is far greater than formerly. While this danger distance has increased, the means for stopping the car have diminished in effectiveness in nearly the same proportion. Combining these results, it will be seen that the actual danger distance for the electric or cable grip car is, probably, six times as great as with the old horse-car.

In applying the hand brake to the motor car there is another loss of efficiency which is not often considered. That is the greater distance run by the car while slack is being taken up before the shoes touch the wheels. With the old-fashioned horse-car brake at average speed, the car would go about 10 ft. before the brake shoes touched the wheels, as about one second was used in taking up slack and getting the shoes into actual contact with the wheels. Increase the speed of a car to twenty miles per hour, and in one second, the time required to bring the brakes against the wheels, the car would move 30 ft., or 37 ft. if the speed be twenty-five miles per hour. With new brake shoes, or in cases where the slack happens to be very small, this may be cut down a little.

This loss of time is a needless waste. The distance made in the first second must be added to the length of time required to stop. In actual practice, with the slack brake rigging and the brake shoes far away from the wheels, a much longer time is taken. Brake ratios vary widely, but

taking as an average 1 : 100 between the handle and shoe, we find that the handle must move 25 in. for each $\frac{1}{4}$ in. movement of the shoe. With a 2 in. slack, the handle must make almost two complete revolutions in addition to taking up slack before the shoe touches the wheel.

With more powerful, quick-acting, brakes both the flatting and the general wear of wheels have been reduced. This has been an unexpected result and one that could not have been foreseen. The explanation appears to be that with a power brake the greatest pressure is applied when the wheels and car are moving most rapidly and when there is the least danger of skidding. As the speed is reduced the pressure upon the brake shoes diminishes to some extent.

Brakes acting on the rim of the wheel must be worked by very powerful levers, and be furnished with very strong springs to bring them back to their primary position. The brake blocks are usually of cast iron, and made in such a way as to be easily replaceable by the removal of a wedge. Means must also be provided for easily and rapidly taking up the wear of the brake blocks. The drawings previously given, Figs. 200, 203, and 212, show the method adopted to fulfil this requirement. On the wear and requirements of brake shoes, Dr. Henry read a very interesting paper at a recent American Street Railway Convention at Atlanta. The Pennsylvania Railroad Company has studied the question very carefully. Tests were made to ascertain the resistance in pounds offered by various types and arrangements of brakes at a uniform pressure of 40 lb. to the square inch, and some of the results obtained are given in Table LX.

TABLE LX.—BRAKE SHOE TESTS.

Type of Brake Shoe.	Wear in Pounds of Brake Shoes during Tests.	Wear of Wheels Expressed in Reduction of Circumference in Inches.	Relative Distance Run after Brake Applied.	Resistance in Pounds Offered by Brakes.
	lb.	in.	ft.	lb.
Chilled cast-iron brake shoe	96.69	2.81	1,834	2,439
Composite (cast and wrought iron) brake shoes	37.63	2.34	1,905	2,356
Steel brake shoes ...	4.53 to 10.22	1.15 to 2.97	2,482 to 3,561	1,773 to 2,077

Average pressure on brake shoes, 40 lb. per square inch. Wheels of car tested made of chilled cast iron.

These tests were made in running by gravity on a uniform descent of 80 ft. to the mile, with three cars weighing approximately 130,000 lb.

Brakes were only used on the foremost car, and in each test the cars were run down one mile and then the brakes put on. From this Table it would seem that the wear of cast-iron brake blocks is the most rapid, but at the same time they appear to have the greatest retarding power. In the wear of the wheels no important difference seems to exist. Brakes and wheels are a function one of the other, and one or other, or both, must wear.

It is preferable to wear out brake shoes rather than wheels, and that must be taken into consideration. It is fairly accurate to say that, on an average, brake shoes last 5,000 car-miles, and chilled wheels 35,000 car-miles, without renewal.

The average weight of a brake shoe may be taken as 21 lb. when new, of which 9 lb. remain when the blocks are discarded, giving a wear of 12 lb. Taking the value of the cast iron thus burnt or ground down at 1d. a pound, and the average annual car mileage of a car at 29,000 miles, the annual value of the brake shoes worn out amounts to just over 23s. per annum per car. The brakes must be quick-acting, and a few turns of the driver's handle should suffice to put them hard on. Strong springs are fitted to bring the shoes off the wheels when the brake handle is let go. To allow easier manipulation of the brake handles, they are connected to the spindle by means of a ratchet arrangement, which enables the conductor to pull the brakes up tight at the most convenient position of the handle.

Besides the ordinary type of wheel brake, a very ingenious combination band and wheel brake has been devised, and is at work on the Oakland and San Leandro Electric Road, California. A drum is attached to one of the car axles; over this, and wound a few times round it, passes a rope. One end of this is attached to a lever on each platform, the other to the brake-rods. By pulling the lever the rope tightens on the drum, which winds it up and puts on the brakes. This system gives great satisfaction.

The introduction of mechanical power and greater speed has caused the adoption of various types of mechanical brakes, two of which have attained considerable success in America. These two are the "Genett" air brake and the "Sperry" electrical brake.

The Genett Air Brake, illustrated by Figs. 233 to 235. An air pump 1, Fig. 233, mounted on the underframe of the car, is worked by an eccentric on one of the axles. Near the top of the air-pump cylinder are two suction and discharge valves, which deliver the compressed air into a small govern-

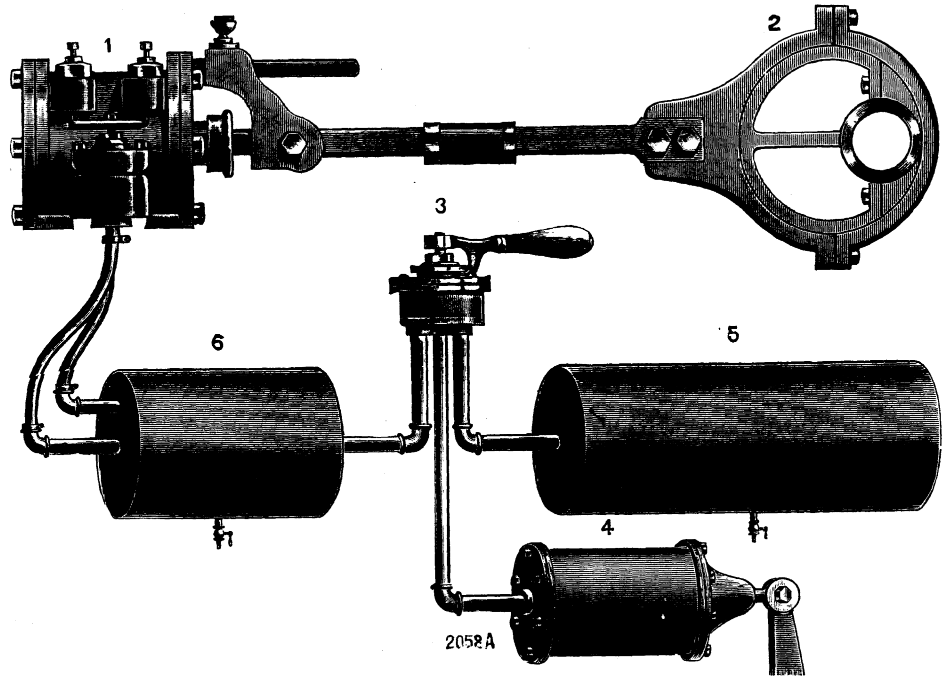
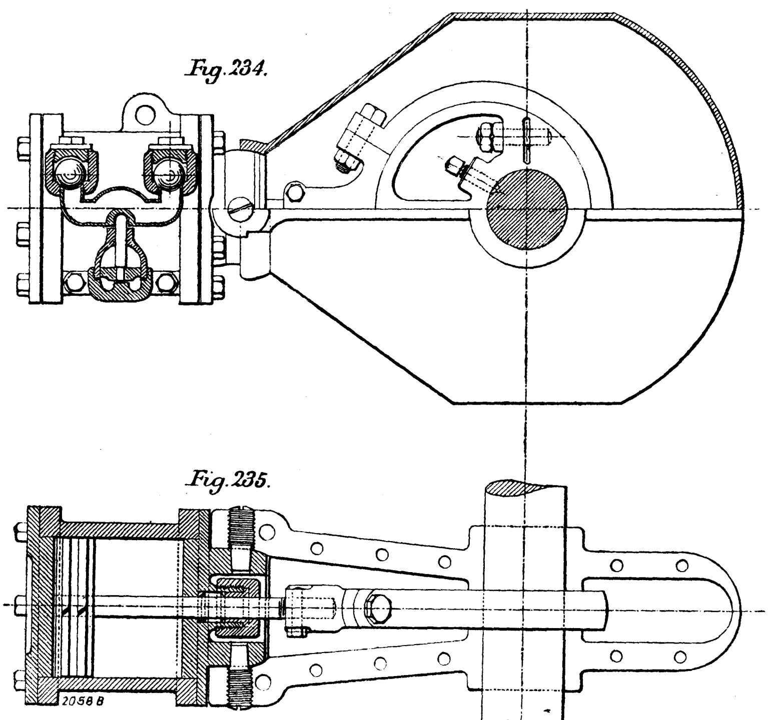


FIG. 233.



THE GENETT AIR BRAKE EQUIPMENT.

ing cylinder placed near the underside of the air pump 1. Within this cylinder is a piston, the rod of which passes through a gland in the top of the cylinder, where it is held by a regulating nut. The piston is held up by the pressure of the air in the reservoir 6, Fig. 233, and a spring round the piston rod tends to force the piston against the compressed air. The amount of pressure thus exerted can be accurately adjusted by turning the regulating nut, and in this way the pressure to be carried in the reservoir is determined. The action of this pump is as follows: As long as the air has not reached the determined pressure to be carried in the reservoir, the pump compresses direct to the reservoirs, and will continue until such pressure is reached. Then the pressure exceeding the force of the spring round the stem of the piston in the regulating cylinder, forces upward the governing piston, and with it a yoke that, automatically lifting the suction valves from their seats, opens the air cylinder and allows the air piston to move in free air, so that it does no work until the brakes are applied; this application uses a part of the air in the reservoirs, reducing the pressure and causing the suction valves to return to their seats, when the compressor is ready to restore the pressure again. The action of the governor piston is sufficiently sensitive for the slightest reduction of pressure in the reservoir to start the pump to work, even though it requires only one stroke to regain the pressure. In starting a journey, it is set so that the compressor fills the reservoirs to a pressure of 30 lb. before the car has travelled 360 ft. In making a stop only 2 lb. or 3 lbs. registered pressure are required, and this the compressor furnishes again before the car has travelled 40 ft., although the reservoirs hold a large excess of the air required to stop the car without any additional supply.

The controlling valve 3 is intended to give full control of the brake work. There are four openings for pipe connections: the first connected with the main reservoir 5, Fig. 233; the second with the auxiliary reservoir 6; the third with the train or brake pipe; and the fourth with the release. The operation of the controlling valve, when connected with the reservoirs and brake cylinder, is as follows: The valve being turned to one position, connects the piping between the reservoirs, and permits the compressor, which is only directly connected with the auxiliary reservoir, to supply both, the air passing through the valve from the auxiliary to the main reservoir until both are charged to the desired pressure.

Turning the valve to a second position connects the main reservoir and the pipe leading to the brake cylinder 4. This applies the brakes, only air

from the main reservoir being used, the valve at the same time having closed the opening leading to the auxiliary reservoir, the full pressure in this latter is maintained.

To release the brakes, the valve is turned to the third position, which connects the train pipe with the release, but still holds the connection closed between the reservoirs. As no air has been taken from the auxiliary reservoir, the compressor valves remain cut out, and allow the car to start without the load of the compressor, until, when running under full headway, the brakesman turning the valve to the first position connects the reservoirs, equalising the pressure, and thereby allowing the compressor to restore the full pressure again. The valve handle is so arranged that it cannot be removed without turning the valve to a position closing all pipe connections. The brake cylinder is constructed on the same principle as that for steam-worked railways.

A modified form of encased compressor is shown, Figs. 234 and 235, which offers some new features for street railway air-brakes. The governing mechanism is the same as that just described, but the eccentric is encased, giving compactness and reducing the chance of derangement; this arrangement, moreover, excludes dust and insures thorough lubrication. The casing is filled with oil, securing perfect lubrication. An advantage presented lies in the ease with which it can be attached to the ordinary street car, there being only two points of suspension, each of which is independent of the other; the case containing the eccentric and strap is attached to the axle; the pump body is suspended from the framework of the car body by a link, and no fitting is required.

The "Sperry" Electric Brake is an extremely ingenious device. Its action is entirely independent of the main current from the trolley wire. When the motor current is turned off, the motor, of course, tends to become a generator, and it is the energy from this source which is used to brake the car.

The brake itself consists of a flat ring, supported from the car frame and not from the axles. When the brake is in action, it is pressed against a faced surface on the inside of the car wheel. The action of gravity holds the brake off normally. The contact surfaces are lubricated by means of a carbon brush which is applied when the brake is brought into action. A coil of wire is so imbedded in the brake ring that when the motor is turned off from the trolley circuit and connected to the coil, the current flowing through it will magnetise the ring and cause it to be attracted by the iron

mass of the car wheel and firmly pressed against it. The action of this brake is due to three different causes, all of which are very powerful—first, to the action of the motor as a dynamo, causing a counter-torque on the axles; second, to the friction between the surfaces of the brake ring and the surfaced car-wheel; and third, and chiefly, to the very heavy Foucault currents engendered in the car-wheel while revolving in the magnetic field of the brake ring. This latter is the greatest retarding force. The great advantages claimed for this brake are that by turning the motor off the brakes are put on, that the brakes cannot be put on till the motor is turned off, and that the current cannot be turned on to the motor till the brakes are off. The stopping is also more gradual, as the moment the car stops the brakes go off of themselves.

A point claimed by the inventor for this brake, and which seems important, is that skidding of the wheels and consequent flats are impossible, as the moment the axles cease to revolve the brake goes off. With the much larger mileage of electric cars, owing to their higher average speed and quicker stops and starts, the number of times the brake has to be applied very much increases, and the labour entailed on the motor-man becomes very severe. Careful records kept on some American city roads show that the number of applications of the brakes average some 1,300 per car per day on a run of 164 miles during 18 hours, or about six brake applications in five minutes. This electric brake depends for its action on the motor, and should an accident happen to the motor it will not work. It would seem, however, that this is not so serious a difficulty as it appears at first sight, for failures of motors are now comparatively rare. In any case, hand brakes ought to be supplied as well, and would be used as emergency brakes.

The higher speed and the noiseless running attained by the mechanically propelled cars has caused the introduction to a very large extent in America of what are called "fenders," or life guards, to prevent people getting under the wheels of the cars. The greater proportion of recorded accidents is due, not to the effects of persons being knocked down, but to the wheels running over them after they have fallen. The motor-man, by means of powerful brakes, as well as by reversing the motors, can bring a car from a high rate of speed to a stop in a very short distance. Therefore, people who come into collision with a car do so for the most part when the car is travelling very slowly, and are not greatly damaged by the collision itself. Some device is, therefore, required

which will either push the person off the track, if he falls down, or pick him up before he comes in contact with the wheels. A very large amount of ingenuity has been shown in constructing such devices, the greater part of them being large, cumbrous, and most unsightly. Some are like huge fishing nets hung in front of the car, and let down by the motor-driver in case of necessity. This arrangement is a mistake, as in case of probable collision the driver has all he can do to stop the car. Others stretch out some distance in front of the car an inch or so above the ground, and are often the cause of the accidents they are meant to prevent; as people

Fig. 236.

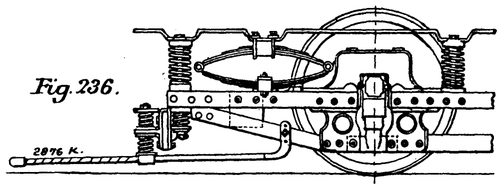
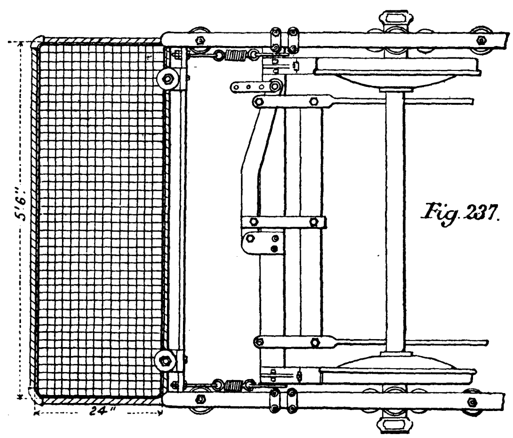


Fig. 237.



THE PECKHAM LIFE AND WHEEL GUARD.

crossing the street misjudge their distance or overlook the fender entirely, and are consequently tripped up. It seems preferable to leave the front of the car entirely free of all obstructions, and to provide a sort of scoop underneath each platform to pick up people who may fall under the car. A fender should under no circumstances be rigid. It must have a large amount of spring, so that it can be carried close to the ground, and also because, if it be stiff, and strikes a prostrate person, it is liable to go over and crush him. Fig. 206, page 170, illustrating the "Imperial" truck, shows a fender fashioned after the style of the "cow-catcher" on American locomotives. Figs. 236 and 237 show a very simple fender, which has the merit of being both cheap and easily applied. It is mounted on springs

and very flexible; this allows of its being run very close to the ground. This fender is under the platform of the car, and does not protrude on any side. The same style of life guard is often affixed to platforms also. Cars should be supplied with fenders at either end, and of such construction that the driver does not have to look after them in any way. As with every other mechanical device, the simpler the fender is, the better.

In dirty and slippery weather a large number of accidents are often due to people slipping on the step of the car while getting on or off. The "Stanwood" step makes slipping nearly impossible; this has been adopted most extensively in America. The tread is composed of thin strips of

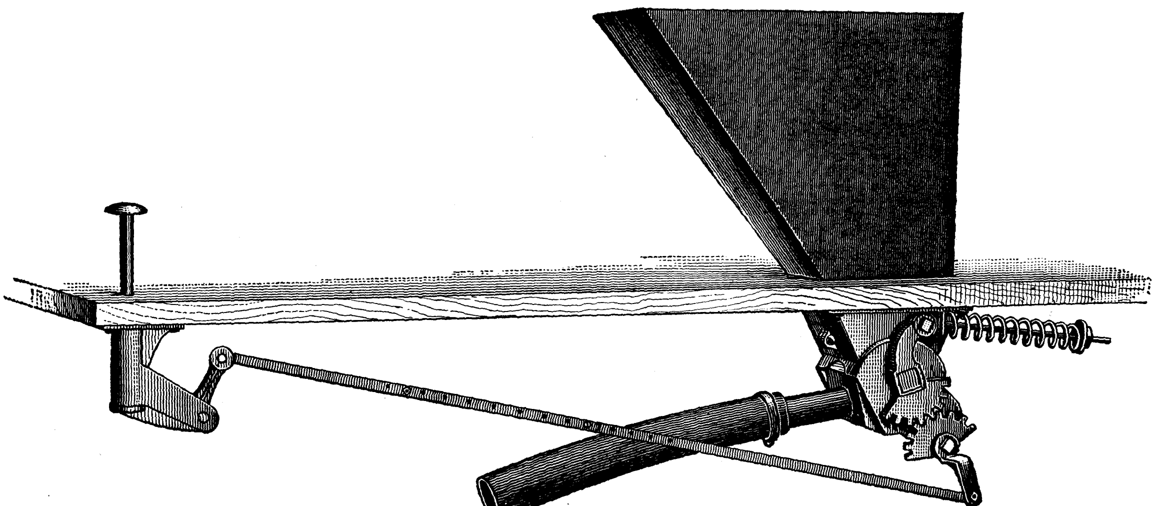
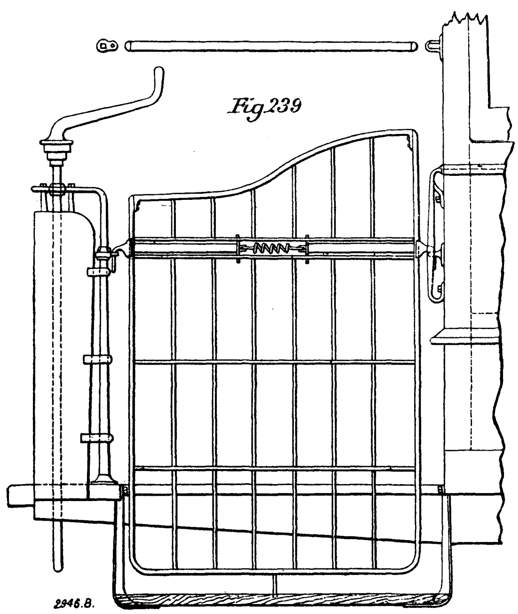


FIG. 238. THE "COMMON SENSE" SAND BOX.

steel, $\frac{7}{8}$ in. wide, square-sheared, and bent alternately in zig-zag shape. These strips are assembled together and interlocked by bosses stamped on them, which prevent vertical motion when they are fixed in their rolled steel frame. A straight strip passes through the centre of the tread and prevents bending. The step is held together by forged iron rods, held in place by nuts. The surface of the tread is $\frac{3}{8}$ in. above the front of the frame. A non-slipping edge is secured by slightly bevelling the first row of the crimped strips. The steel strips being square-sheared, prevent the boot from slipping; and, as the apertures formed by the strips are only $\frac{3}{4}$ in., the sole of the boot does not round off the edges, but keeps them sharp. The openings allow free passage of dirt and snow, and form a good scraper, thus preventing accidents from slipping, and conducing to the cleanliness of the cars.

In consequence of the heavy weights carried and the severe gradients met with on electric lines, sand-boxes are nearly universally used. There are numerous different constructions, the great point being simplicity of design. They are generally worked by the driver pressing a button with his foot. Fig. 238 shows a sand-box which is much used, and has been adopted by the Bristol and Dublin electric lines.

The alarm signal in nearly universal use is a bell under each platform, worked by a button in the same way as the sand-box. In some cases



SAFETY GATE.

electric bells, worked by a storage battery, are used. Where compressed air is employed to work the brakes, a horn or whistle has been adopted.

SAFETY GATES.—Fig. 239 shows a very simple and effective safety gate. An arrangement of this kind is absolutely necessary where mechanical traction is used, to prevent people getting off on the wrong side of the car, with the liability of being run over by a car coming in the opposite direction. The use of these gates is nearly universal in America.

A form of collapsible safety gate which folds up when not in use is shown in Fig. 226, page 187. This is a more sightly and workmanlike device than that shown in Fig. 239.

CHAPTER XIV.

THE TROLLEY.

THE earliest form of trolley consisted of a four-wheeled truck, running upon the two elevated conductors then considered necessary. This was connected to the car by means of a flexible insulated cable, and was towed along the conductors behind the car.

The next form, employed when the single trolley wire had demonstrated its superiority over the double-wire system, consisted of a spring-supported pole or framework, with a frictional contact sliding along the under surface of the wire. The wear on the trolley wire where these contacts were employed proved to be excessive, and they were abandoned for the present wheel.

As in the case of all electric tramway supplies, the earlier types were comparatively clumsy, and the old form of trolley base occupied a great deal too much room on the roof of the car.

The base of the latest "Boston Pivotal" type is shown in Fig. 240. This base is of simple construction—neat, compact, and designed to allow of its passing under low bridges. Experience has proved it to be smooth-running, easy of adjustment, strong, and durable. It lies close to the roof of the car, and can be swung around whenever it is desired to change the direction of the car. With its pole laid down flat, the highest point on the base is but 6 in. above the roof. To avoid overtaxing the springs which support the trolley pole and wheel, so that they will set or break, a very large safety factor is allowed. A special construction insures an even pressure of the wheel against the trolley wire in the different positions. The "Boston Pivotal" Trolley, shown in the illustration, received the highest award at the World's Columbian Exposition at Chicago.

The trolley pole is of one piece of steel with a continuous taper, and without joints, shoulders, or other points of weakness. It is light, strong, and stiff. If bent by an accident, it can be straightened cold. The trolley fork, Fig. 241, is of a new pattern, tapering in form, of sheet-steel, light and strong, provided with phosphor-bronze contact springs and washers,

which have proved far more durable than those of copper. The spindle is of hardened steel.

Great attention has been paid to the development of a first-class trolley wheel. The earlier form of wheel was made of a single bronze casting and with the V-shaped groove then considered best. A *substantial* improvement upon the earlier form was made when a built-up wheel was

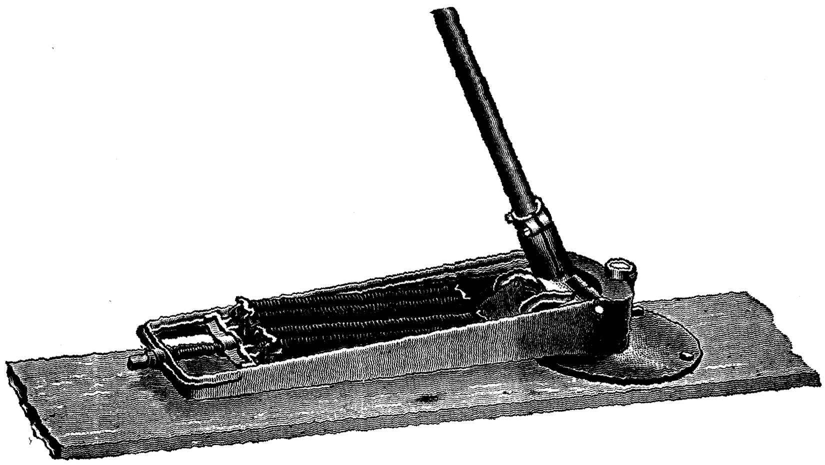


FIG. 240. BASE OF "BOSTON PIVOTAL" TROLLEY.

FIG. 241. TROLLEY FORK.

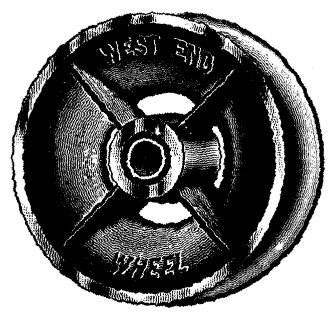


FIG. 242. "WEST END" TROLLEY WHEEL.

roduced. In this a very substantial hub was provided to take the ıdle. Iron guard plates were riveted on either side to prevent the ey jumping the wire. The wear was taken up by a contact ring, which ' be removed and replaced as needed, but at considerable expenditure ıe and trouble. The shape of the groove was changed to an almost ·cular form. These were in turn abandoned in favour of the " West ·heels now universally used (Fig. 242). These are made of a single

bronze casting, having a wide and highly-polished groove, and being furnished with either graphite or self-oiling bushings to receive the spindle. The difficulty found in using the older form of brass trolley wheel was that the flange dropped off when the groove which received the trolley wire wore through to the outside, as it of course must do in time, on account of constant friction against the trolley wire. In the "spoked" trolley wheel this difficulty is entirely obviated by a simple and effective method of construction. The ribs serve to hold the flange in position after the sparking of the wheel indicates that it is worn through and therefore should be discarded. This warning is timely, for the wheel may be used after the flange is cut through by the trolley wire, long enough to get to the car house, where a new wheel can be put in. With the old form of brass wheel, when the flange wore through and dropped off, the car was disabled, and had to be pulled to the car house or removed from the track. If this breakdown occurred in a crowded thoroughfare, or in an out-of-the way place where it was not easy to obtain assistance, the awkwardness of the situation and the annoyance resulting from it were obviously great.

The life of a trolley wheel naturally depends upon the nature of the individual line and the service. It may run without wearing through from 3,500 to 6,000 miles.

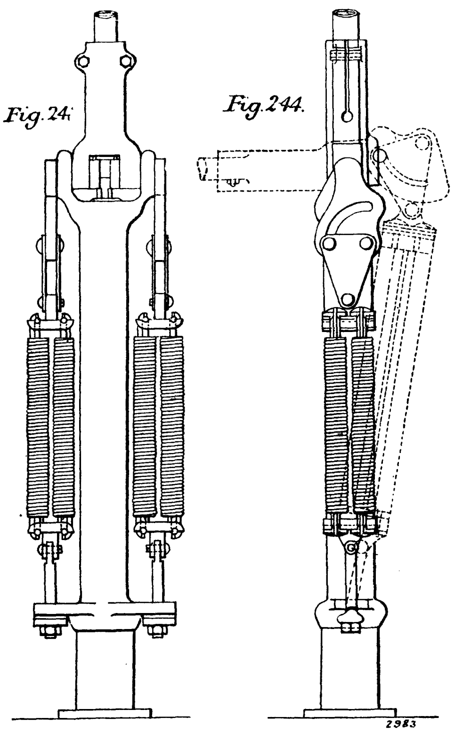
The trolley base should be firmly bolted to the trolley board attached to the roof of the car. This board strengthens the roof, and protects it from damage. It also deadens the noise of the trolley.

Mather and Platt in Great Britain, and Siemens and Halske in Germany, have used a simple T or arch-shaped steel or iron bar having strong springs tending to bring it to a vertical position. This bar slides along the bottom of the wire. The objection is the hissing noise made by the collector sliding along the wire and the much more rapid wearing out of the latter. To prevent grooves being worn in the collector bar, the wire is hung in a zigzag across the road. Not more than 5 per cent. of the electric roads at present running in all parts of the world are using anything besides the ordinary American type of trolley, which has proved itself in the last 10 years to be the best mode of collecting the current of the trolley wire. The American Sprague Company used for some time a T scraping contact in 1887, but eventually abandoned it.

It will readily be appreciated that the type of trolley described above, is unsuited for use with the ordinary roof-seat cars familiar to English eyes.

Roof-seat cars, of the style here used, are practically unknown in America, the climate requiring that a roof of some kind should be afforded for the protection of passengers in those sections of the country where the summer heat is most intense, while in the North the severe winters require a closed-in upper deck. Therefore, in all cases in America a roof is to be found to which the trolley base can be firmly attached.

When it became necessary to adapt American practice to English conditions, the modified form of trolley base, shown in Figs. 243 and 244,

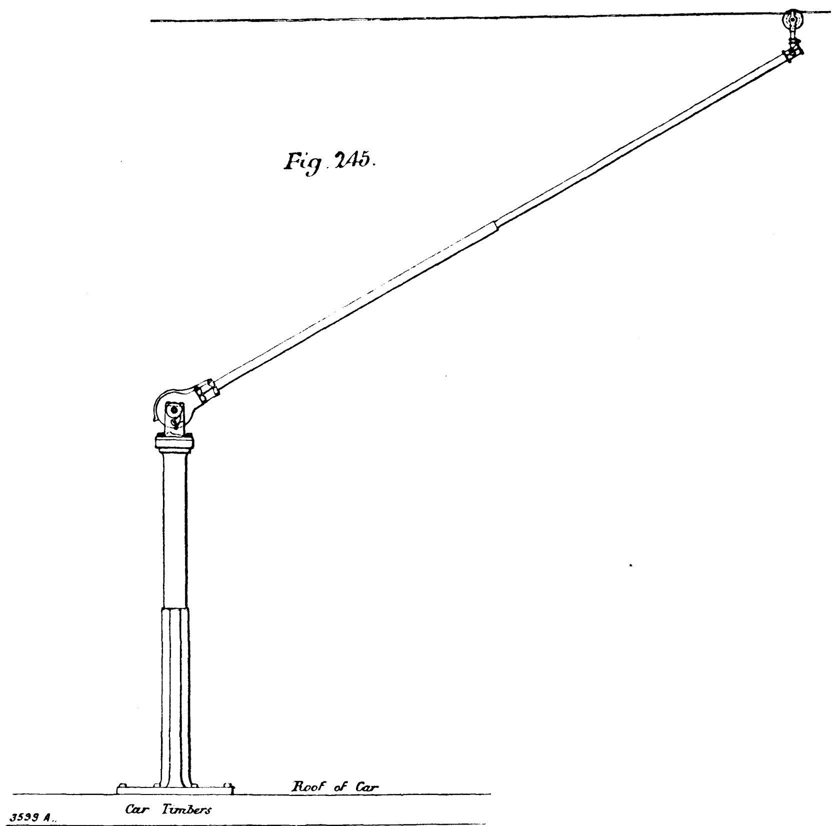


Roof-Seat Car Trolley Standard.

was evolved by Mr. R. W. Blackwell, of London. As will be seen from the illustrations, the base of the trolley, with the connecting springs, is arranged vertically instead of horizontally, but the action is practically the same. In order to enable the trolley to be reversed in direction at the end of the route, ball bearings are provided at the top and base of the section which carries the springs, allowing as easy rotation of the upper section as is obtained in the pivotal horizontal trolley. To secure entire insulation of the base, springs, and lower section of the pole, which are within easy reach of the passenger, the trolley wheel is connected with the motors by means

of an insulated cable running through the centre of the trolley pole, and the upper extremity of the pole itself may be made of wood instead of tubular steel or wrought iron. As shown in Figs. 243 and 244, the trolley is arranged to come up through the back of the seats of a "knife-board" car. Where garden seats are used, the lower casting is prolonged to such an extent as to reach the flooring of the upper deck, and can occupy any desired position upon the roof, it of course being preferable, so far as easy operation is

Fig. 245.



SIDE-ACTING ROOF-SEAT CAR TROLLEY AT BRISTOL.

concerned, to locate it centrally. A very ingenious contact is arranged at the base of the trolley pole, connecting the insulated cable coming from the wheel with a shaft conductor extending down through the base, thus avoiding any danger of the conductor being twisted off should the trolley be repeatedly turned around upon its axis in the same direction. With a garden-seat car the height from the lowest part of the base to the axle upon which the pole is mounted, is usually 6 ft. 6 in. The tubular upright casting is 4 in. in diameter.

These trolleys are used on the Dublin, Bristol, Coventry, and Isle of Man Electric Tramways.

At Dublin, the trolley standard occupies the room of one passenger, taking the place of a seat next to the aisle. On this line the trolley wire is, along the straight line, over the centre of the track ; the trolley wheel consequently must always run at a slight side-angle to the trolley pole. At curves it follows the wire readily to 4 or 5 ft. off the central line of the tracks. At Bristol much more onerous conditions prevail, for along the greater part of the line the trolley wire is from 3 to 10 ft. off to one side of the car, and the trolley must follow the path of the wire without attention and without any slackening of speed, having, in fact, to run faster than the car whenever the line of the trolley wire deviates from that of the track. It has successfully filled these requirements, and has made it possible to utilize the system of bracket-arm supension of trolley wire from single poles along one side of the street to a much greater extent than has heretofore been deemed possible.

An improved type of side-acting trolley has lately been brought out by Mr. Blackwell, and is now on trial at Bristol, bidding fair to take the place of the one last described. It is shown in Fig. 245. All the springs are encased in the box at the top of the trolley standard, and their tension can be increased or loosened equally and at the same time without trouble and at a moment's notice. This is a most valuable feature. All the connections and insulating parts have been greatly strengthened, and the various details of construction have been improved in the light of the experience obtained on the Bristol and Dublin lines.

CHAPTER XV.

THE POWER HOUSE.

THE success or failure of an electric line depends to no small extent upon the location and design of the power station. The conditions which govern its erection are in many ways entirely different from those which have to be considered in the construction of an electric lighting plant. The load is a constantly varying factor, and the variations are very large and unexpected. Breakdowns are more serious than in lighting plants, and such precautions must be taken as will render a suspension of service practically impossible under any circumstances.

In many instances the station must be in continuous operation for several consecutive days. The writer has frequently seen units in large American power houses which have been running for eight and ten days continuously.

Before proceeding to describe in detail the various parts which compose a power station, it may be well to say a few words as to how the amount of power required for a given line and traffic may be determined.

Given a line having a certain mileage, a stated headway upon which it is desired to run cars, and the average speed at which they are to run, Table No. LXI. shows how to determine the number of cars.

We have previously shown how to determine the average power required by each car under various conditions of grades and speed. It has also been shown that the average power required by each car is not the only thing to be considered, as, at moments, much larger demands are made by the cars. It is evident that on a line having only a few cars, these heavy calls for power may require a very much larger engine plant than might be considered necessary from the average power used by each car. Therefore, in a large plant, the engines can be run more economically than in a smaller installation, their average load being nearer their maximum power.

Table No. LXII. approximately demonstrates this advantage, and holds good for lines having no very severe gradients, and average speeds

of about eight to ten miles an hour. It will be seen from this Table that whereas a small line running five cars requires 35 indicated horse-power per car at the power station, lines operating 50 cars are sufficiently equipped with 15 indicated horse-power per car. This Table has been made up from the average of a very large number of American electric roads.

TABLE LXI.—NUMBER OF CARS ON TEN MILES OF TRACK, VARIOUS SPEEDS AND HEADWAYS.

Minutes Apart or Headway	Average Speed in Miles per Hour.									
	6	7	8	9	10	12	15	20	25	30
1	100	86	75	67	60	50	40	30	24	20
2	50	44	38	33	30	25	20	15	12	10
3	33	29	25	22	20	17	13	10	8	7
4	25	22	19	14	15	13	10	8	6	5
5	20	17	15	13	12	10	8	6	5	4
6	17	14	13	11	10	8	7	5	4	3
7	14	12	11	10	9	7	6	4	3	3
8	13	11	9	8	8	6	5	4	3	3
10	10	9	8	7	6	5	4	3	2	2
15	7	6	5	4	4	3	3	2	2	1
20	5	4	4	3	3	3	2	2	1	1
30	3	3	3	2	2	2	1	1	1	1

TABLE LXII.—APPROXIMATE INDICATED HORSE-POWER AT POWER HOUSE REQUIRED FOR VARIOUS-SIZED CAR EQUIPMENTS.

Number of Cars.	Indicated Horse-Power per Car.
1 to 5	35
5 „ 10	30
10 „ 15	25
15 „ 25	20
25 „ 50	15

Fig. 246 is a diagram resulting from a series of ammeter readings taken every ten seconds in the power-house of the Baltimore City Passenger Railway Company. Forty-four motor cars, running at an average speed of 10 miles an hour, were in service. The voltage varied between 500 and 540 volts, the average being about 520. A glance at this diagram will show how extremely variable the load is in electric railway practice. Within four seconds 800 additional horse-power were required at the switchboard.

When electric traction was first introduced in America, great mistakes were made in the choice of the units adopted. These, however, are now

being corrected, and in this connection it may be interesting to inspect Table No. LXIII., which is taken in part from a report made at the twelfth annual meeting of the American Street Railway Association.

TABLE LXIII.—SIZES OF UNITS RECOMMENDED FOR USE IN POWER HOUSES.

Maximum Indicated Horse-Power Required to Work Road.	Number of Engines Recommended.	Indicated Horse-Power of each Engine.
200	2	200
400	3	200
600	3	300
1,000	3	500
1,500	4	500
2,000	4	750
5,000	6	1,000
10,000	8	2,000

In early days the units employed were far too small and weak. At the present day dynamos for railway purposes are so constructed that accidents to them are quite as rare as to the driving engines themselves. Countershafts have been abandoned to a great extent, as wasteful in power and useless. Very large reserves of power were also installed on the earlier electric lines. This practice has been abandoned. The Table already referred to shows the reserve power which should be allowed. A sufficient number of engines are provided to furnish the maximum horse-power required to run the road, with a surplus of one engine in reserve. With this reserve the engineer can keep his plant in perfect adjustment and repair, one engine being at all times stationary. In case of a breakdown, this extra engine is ready to take the place of the one disabled.

A great diversity of opinion exists among street railway engineers as to whether the engines should drive the generators by belts or ropes, or be directly coupled. The great objection advanced against direct coupling is the want of elasticity, which, in case of sudden and heavy overloading, might cause a breakdown of the engine. It is said that belts and ropes act as a spring, and prevent these sudden shocks damaging the engine. Another reason which causes belts and ropes to be so largely used is that smaller plants running at higher speeds can be used with belts than would be possible with direct coupling, thus effecting a substantial economy in the prime cost of the installation.

It, however, seems to be beyond doubt that for large plants having units of 500 horse-power and upwards, slow-speed, direct-coupled, hori-

TABLE LXIV.—Comparative Table of Horse-Power, Fuel Consumption, Water Consumption, Cost, &c., for One 1,000 Horse-Power Plant for Electric Railroad.

—	Single Cylinder Short Stroke Non-Condensing Engines.	Single Cylinder Long Stroke Non-Condensing Engines.	Single Cylinder Short Stroke Condensing Engines.	Single Cylinder Long Stroke Condensing Engines.	Compound Short Stroke Non-Condensing Engines.	Compound Long Stroke Non-Condensing Engines.	Compound Short Stroke Condensing Engines.	Compound Long Stroke Condensing Engines.	Triple-Expansion Short Stroke Condensing Engines.	Triple Expansion Long Stroke Condensing Engines.
Consumption of dry steam per h.-p. per hour, theoretical .. lb.	20-27	20-27	15-19	15-19	18-25	18-25	12-15	12-15	9-11	9-11
,, ,, ,, practical .. ,,	30	30	20	20	25	25	16	16	13	13
,, ,, 1,000 h.-p. per hour, practical ,,	30,000	30,000	20,000	20,000	25,000	25,000	16,000	16,000	13,000	13,000
,, water per day of 18 hours, practical.. ..gals.	64,800	64,800	43,200	43,200	54,000	54,000	34,500	34,500	28,000	28,000
,, ,, year of 365 days, practical .. ,,	23,000,000	23,000,000	15,700,000	15,700,000	20,700,000	20,700,000	12,600,000	12,600,000	10,220,000	10,220,000
,, combustible per h.-p. per hour, practical .. lb.	3.75	3.75	2.5	2.5	2.5	2.5	1.6	1.6	1.3	1.3
,, ,, 1,000 h.-p. per hour, practical, tons	1.875	1.875	1.250	1.250	1.250	1.250	.8	.8	.65	.65
,, ,, day of 18 hours, practical .. ,,	33.75	33.75	22.50	22.50	22.50	22.50	14.40	14.40	11.70	11.70
,, ,, year of 365 days, ,, .. ,,	12,318	12,318	8,212	8,212	8,212	8,212	5,256	5,256	4,270	4,270
Boiler pressure in pounds per square inch, practical	60-100	60-100	75-100	75-100	90-110	90-110	90-130	90-130	125-180	125-180
Style of Boilers .. .. R.T. = Return tubular	R.T.	R.T.	R.T.	R.T.	Water-tube	Water-tube	W.T.	W.T.	W.T.	W.T
Square feet of heating surface to the h.-p.	15	15	15	15	12	12	12	12	12	12
Evaporating capacity per sq. foot of heating surface per hour lb.	2½	2½	2½	2½	3	3	3	3	3	3
Boiler h.-p. required for plant, theoretical	1,000	1,000	700	700	800	800	475	475	360	360
,, ,, practical	1,100	1,100	875	875	900	900	650	650	560	560
Proportion of boiler power to engine power, theoretical per cent.	100	100	70	70	80	80	47.5	47.5	36	36
,, ,, ,, practical ,,	110	110	87.5	8.75	90	90	65	65	56	56
,, engine cylinders, practical	..	..	..	..	1 to 3-4	1 to 3-4	1 to 3-4	1 to 3-4	1-2¾-5	1-2¾-5
Average piston speed in feet per minute, practical	600	600	600	600	600	600	600	600	600	600
Variation in speed from no load to full load .. .. per cent.	1-2	4-6	1-2	4-6	1-2	4-6	1-2	4-6	1-2	4-6
Cost of plant all erected with foundations and iron stacks, building not included, approximate, per h.-p.	£ s. d. 8 12 0	£ s. d. 10 12 0	£ s. d. 9 12 0	£ s. d. 11 12 0	£ s. d. 11 4 0	£ s. d. 13 0 0	£ s. d. 11 8 0	£ s. d. 13 4 0	£ s. d. 12 12 0	£ s. d. 14 8 0
Cost of fuel per h.-p. per year, approx. (Cost of fuel, 16s. per ton.)	10 2 0	10 2 0	6 14 0	6 14 0	6 14 0	6 14 0	4 5 0	4 5 0	3 10 0	3 10 0

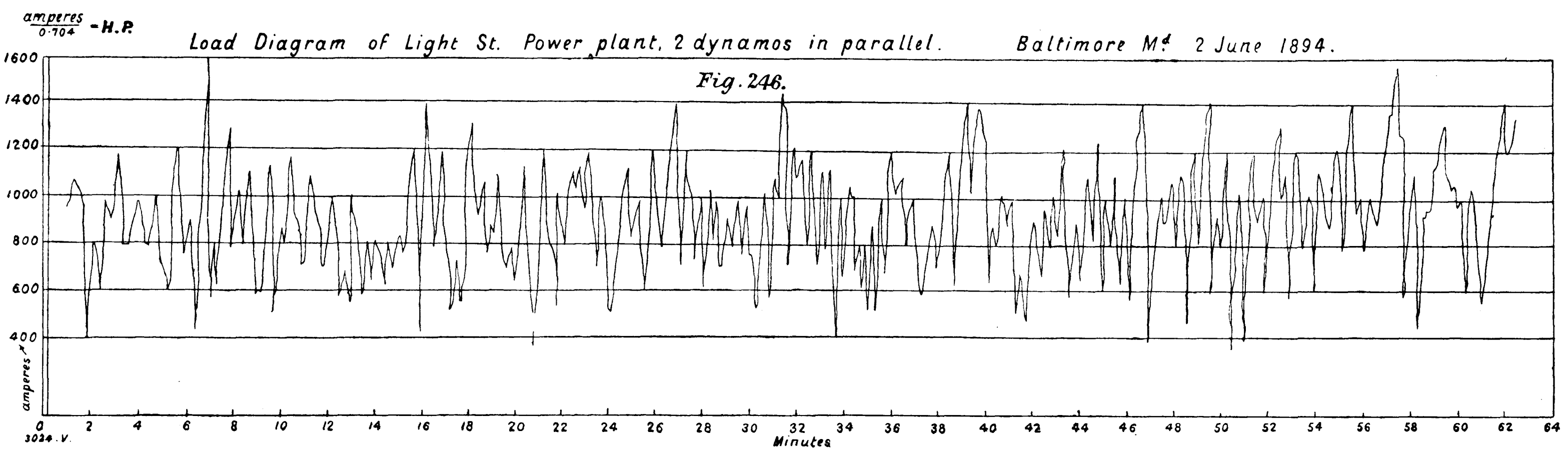


Diagram of Current generated in Power House.

zontal or vertical compound condensing engines are preferred in America. Notwithstanding that America is the home of the high-speed engine, direct-coupled high-speed plants are comparatively rare, although high-speed belted engines are very much used. In this connection, Table LXIV., for which the writer is indebted to the courtesy of The Pierce and Miller Engineering Company of New York, is interesting. The prices and quantities given are probably slightly high, but the comparison may be considered fairly accurate on the whole.

It is undoubtedly the case that the direct-coupled system is steadily gaining ground, and should be used in units of 150 K W and upward, if not in smaller units as well.

Stations should always be built as compact as possible, but space, light, and above all, ventilation, should never be grudged in the engine-room.

Access should be easy and direct to the boiler-room. For small stations, one building divided by a glass partition between engines and boilers is advisable, as it renders supervision easier.

Whether vertical or horizontal engines are adopted seems to depend primarily upon the available space, and secondly, and to a very large degree, on the fancy of the designing engineer. So far, horizontal engines are mostly used in America, although there are now some very fine stations where triple-expansion condensing marine engines are employed, each directly coupled to two generators. A very good example of such a station is to be found at Milwaukee.

A question of the greatest importance is the choice of site for the power house. In most cases the engineer's hands are tied by local conditions, and his choice is restricted to two or three sites which in most cases would not be considered by him if he were left free. The first, and possibly most important, consideration is to locate the power station as nearly as possible in the distributing centre of the lines to be furnished with current. It often happens, however, that this position is either unobtainable, or that it is extremely inconvenient from the point of view of water and coal supply. In large installations an easy method of getting out of this dilemma is to use high-tension alternating currents. By this means the power station can be located at a considerable distance from the centre of distribution. Sub-stations can then be installed, to which the high-tension alternating current is conducted, and there, by means of rotary transformers, it is changed into the ordinary 500-volt continuous current.

A very interesting British example of this kind is that of the Dublin Electric Tramways, which is described at length in a later chapter.

Where water power is obtainable, and where its use would not imply heavy engineering works, the use of turbines is highly advantageous. There are numerous examples, both in Europe and America, of the successful adaptation of water power to electric traction, and some of the most interesting of these plants are described at length hereinafter. It may, however, be mentioned that difficulty is sometimes found in regulating the power and speed of the turbines under the very exceptional fluctuations in load to which the power plants of electric tramways are subjected. With the increasing size of the station, however, the proportion of fluctuations in power to the total output rapidly decreases, and the use of water power becomes easier.

We will consider the general parts which compose an electric traction plant using steam power under the following headings:

Engines.	Switchboard.	Auxiliary appliances.
Dynamos.	Boilers.	General considerations affecting design.

ENGINES.—The engines in electric traction stations have to deal with far greater fluctuations in load than arise in any other kind of work, not even excepting rolling mills. Therefore care should be taken to strengthen all their component parts, so that they will be able to stand these extremely variable loads. This fact has now been fully grasped in America by the best builders of engines, and as in the case of all machinery used in modern electric street railway installations, engines are specially designed with a view to the strains from constant and sudden variations of load and overloading.

A most important point is the flywheel. As the average output of an engine in traction work is generally from one to two thirds of the maximum load, it follows that if the engine were built with a view to taking full load it would ordinarily be working with a very low efficiency. The usual practice, therefore, is to employ engines the greatest efficiency of which is reached when running at about two-thirds of the maximum power required. As seen from a load diagram of an electrical railway previously given, the very heavy loads come on for a period of a few seconds only. The engines are therefore furnished with flywheels having a weight such that their live energy is able, during a few seconds, to give out the extra amount of work called for.

It will be seen, therefore that the heavy rim of a flywheel in an electric tramway power-house does not merely serve, as in most other instances, as Rankin puts it, to "reduce the coefficient of fluctuation of speed to a certain fixed amount," varying in most cases between $\frac{1}{32}$ to $\frac{1}{60}$, but that its chief object is to take care of momentary overloads.

If I is the moment of inertia of the flywheel, $\frac{1}{m}$ the coefficient of fluctuation permitted, g the acceleration (32.2 ft. per second), ΔE the energy the flywheel has to furnish during one period, a_0 the mean angular velocity, then we may admit:

$$I = \frac{m\,g\,\Delta\,E}{a_0}$$

from which we get the moment of inertia of the required flywheel. Rankin gives as the usual mean radius of the flywheel on steam engines from three to five times the length of the crank. Or we may take another approximate formula which will give us the weight W of the flywheel in tons, if the mean radius R in feet, the number of revolutions n per minute, the coefficient M giving the value of the relative variation in speed permitted, aud the variation of energy Δ E during one revolution in foot-tons are given. Then we have approximately

$$W = \frac{545 \times \Delta\,E}{n^2 \times R^2 \times M\,(m+2)}.$$

The weight of the rim of the wheel may be taken to be between 80 and 90 per cent. of the total weight of the flywheel. As will be seen from the Tables of dimensions of steam engines and flywheels of American makers, the speed at the pitch line is considerable. In several cases in America it reaches over 70 ft. per second, or considerably more than is usually considered safe in Europe, where from 30 ft. to 50 ft. per second is the peripheral speed mostly adopted.

Tables LXV. to LXIX. are of interest as showing the heavy weight of engine and flywheel both in high and low speed engines by some of the largest American manufacturers.

The McIntosh and Seymour engine may be considered as the best of the electric railway and power engines which have been developed in the United States. It has been especially designed and constructed for this service. A large number of these engines are now being put in for railway power stations both in Great Britain and on the Continent.

Another point of the utmost importance is that the regulation or governing of the engine be such that under no circumstances is there any liability for the engine to race, as this is nearly always attended with most disastrous results. The governor should be so constructed that under any variation of load, from normal load to no load, the speed of the engine should be maintained constant within 2 per cent.

TABLE LXV.—McIntosh and Seymour's "Railway Compound" Engines. Condensing and Non-Condensing, with two Extra Heavy Flywheels. Horizontal, Tandem, Double Crank. Condensing Engines.

Nominal Indicated Horse-Power.	Range of Initial Pressure.	Diameter of High-Pressure Cylinder.	Diameter of Low-Pressure Cylinder.	Stroke.	Revolutions per Minute.	Floor Space Occupied by Engine. Length.		Width.		Size of Steam Pipe.	Size of Exhaust Pipe.	Size of Each Flywheel. Diam.	Face.	Weight.	Weight of Engine.
	lb.	in.	in.	in.		ft.	in.	ft.	in.	in.	in.	in.	in.	lb.	lb
90	90-110	9	16	11	260	13	5	5	3	3½	7	66	12½	2300	11,500
110	90-110	10	17½	13½	245	10	0	5	9	3½	7	70	13½	2800	14,400
140	90-110	11	19	15	235	15	10	6	1	4	8	74	14½	3400	18,000
215	90-110	13	23	17	210	17	3	8	0	5	10	82	18½	4500	29,500
425	110-120	15	26	17	200	18	5	8	7	6	12	86	22	6000	39,000
400	110-120	16½	29	17	195	19	2	9	6	6	12	88	26	7000	46,750
500	110-130	18	32	19	175	22	2	11	4	7	13	108	32	8000	66,500
110	120-130	9	16	13½	245	15	0	5	9	3½	7	70	13½	2800	14,000
325	140-160	13	23	17	200	17	5	8	7	5	10	86	22	6000	36,000
400	140-160	15	26	17	195	19	2	9	6	6	12	88	26	7000	43,250
500	140-160	16½	29	19	175	22	2	11	4	6	12	108	32	8000	63,500
Non-Condensing Engines.															
90	90-100	10½	16	12	260	13	5	5	3	3½	7	66	12½	2300	12,000
115	90-110	12	17½	13½	245	15	0	5	9	4	7	70	13½	2800	15,000
150	90-110	13	19	15	235	15	10	6	1	5	8	74	14½	3400	18,500
220	90-110	15	23	17	210	17	3	8	0	5	10	82	18½	4500	30,500
325	110-120	16½	26	17	200	18	6	8	7	6	12	86	22	6000	40,000
400	110-140	18	29	17	195	18	4	9	6	7	12	88	26	7000	47,750
500	120-130	20	32	19	175	22	2	11	4	7	13	108	32	8000	67,500
325	130-150	15	23	17	200	17	5	8	7	5	10	86	22	6000	37,500
400	130-150	16½	26	17	195	19	2	9	6	6	12	88	26	7000	44,250
500	150-160	18	29	19	175	22	2	11	4	7	12	108	32	8000	64,500

TABLE LXVI.—McIntosh and Seymour's "Railway Single Cylinder" Engines. Steam Pressure 90 lb. to 110 lb. Horizontal Double Crank.

Nominal Indicated Horse-Power.	Size of Cylinder. Diameter.	Stroke.	Revolutions per Minute.	Floor Space Occupied by Engine. Length.		Width.		Size of Steam Pipe.	Size of Exhaust Pipe.	Size of each Flywheel. Diameter.	Face.	Weight.	Weight of Engine.
	in.	in.		ft.	in.	ft.	in.	in.	in.	in.	in.	lb.	lb.
65	11	12	270	10	0	5	3	3½	4	64	12½	2,000	9,000
80	12½	12	270	10	0	5	3	4	5	64	12½	2,000	9,750
100	13	15	245	11	8	6	1	5	6	70	14½	2,800	12,250
125	14½	15	235	11	10	6	1	5	6	74	14½	3,400	14,751
150	16	15	235	11	10	6	1	6	7	74	14½	3,400	15,500
200	18½	17	210	13	6	8	0	7	8	82	18½	4,500	22,000
200	18½	18	200	13	8	7	11	7	8	86	17	4,500	22,500
325	23	17	200	14	4	8	7	8	10	86	22	6,000	29,500
400	26	17	195	14	10	9	6	9	12	88	26	7,000	38,250
500	29	19	175	17	0	11	4	10	12	108	32	8,000	55,500
325	18½	17	200	13	8	8	7	7	8	86	22	6,000	28,500
400	23	17	195	14	10	9	6	8	10	88	26	7,000	35,250
500	23	19	175	17	0	11	4	8	10	108	32	8,000	53,500
500	26	19	175	17	0	11	4	9	12	108	32	8,000	54,500

TABLE LXVII.—GIVING CHARACTERISTICS OF STANDARD AMERICAN DIRECT-CONNECTED ENGINE GENERATORS.

Dynamo Capacity.	Engine Capacity. (Horse-Power.)	Speed. (Revolutions per Minute.)	Engines.			Weight per Horse-Power.	Horse-Power per Sq. Ft.	Dynamos.					
			Weight.		Floor Space.			No. of Poles.	Weight.		Floor Space.	Weight per Engine Horse-Power.	Engine Horse-Power per Sq. Ft.
			Engine (total).	Fly-wheel.					Total.	Armature.			
kilowatts.			lb.	lb.	sq. ft.				lb.	lb.	sq. ft.		
225	255	120	90,000	25,000	485	353	.526	6	37,000	14,520	54	123	5.55
300	340	100	120,000	30,000	520	353	.654	6	60,400	20,720	78	151	5.13
400	455	100	135,000	40,000	546	297	.833	8	71,440	30,580	90	134	5.92
400	455	80	150,000	50,000	600	329	.758	8	74,250	31,480	96	139	5.55
500	567	75	180,000	60,000	640	317	.886	10	87,150	35,800	95	131	7.01
800	907	80	240,000	85,000	910	265	.997	10	110,000	49,440	115	103	9.27
1,500	1,800	75	450,000	150,000	1,386	250	1.299	12	163,200	73,100	144	82	13.90

TABLE LXVIII.—BASS-CORLISS ENGINES.

Diameter. in Inches.	Stroke in Inches.	Revolutions.	Piston Speed in Feet.	Indicated Horse-Power. 100 Pound. $\frac{1}{4}$ Cut-off.	Flywheel.		
					Diameter in Feet.	Face in Inches.	Weight in Pounds.
14	30	90	450	116	10	17	8,000
16	36	82	492	162	12	21	10,600
18	36	80	480	199	12	25	13,000
18	48	75	600	249	15	25	15,500
20	48	72	576	296	16	29	19,000
22	48	72	576	368	16	31	23,400
24	60	65	650	481	18	37	30,200
26	60	65	650	564	18	37	32,000
28	60	65	650	654	18	37	32,000
30	60	62	620	717	24	52	39,000
30	72	55	660	762	24	60	52,000
32	72	55	660	868	24	66	58,500

TABLE LXIX.—REYNOLDS-CORLISS SINGLE CYLINDER ENGINES.

Diameter of Cylinder in Inches.	Stroke in Inches.	Revolutions per Minute.	Indicated Horse-Power at $\frac{1}{4}$ Cut-Off and 140 lb. Steam Pressure.	Flywheel.			Main Bearing.	
				Diameter in Feet.	Face in Inches.	Weight in Pounds.	Diameter in Inches.	Length in Inches.
12	30	90	116	9	15	5,700	6	12
16	36	82	226	12	21	10,000	8	14
20	42	75	376	15	25	16,600	10	17
24	48	70	577	18	35	24,400	12	20
28	48	68	765	20	44	31,500	14	22
32	48	65	955	24	48	34,500	16	24
36	48	62	1,152	24	56	44,300	18	32
38	60	60	1,539	26	...	59,000	19	32
40	48	70	1,605	24	...	54,700	20	36
42	60	62	1,960	26	...	72,000	21	36
44	60	62	2,150	26	...	79,000	22	38
46	72	55	2,502	30	...	95,000	23	38
48	72	55	2,726	30	...	106,600	24	42

A condition called for by the very heavy fluctuations in load is that the cut-off should be able to be varied between, say, one-tenth and seven-tenths of the stroke.

In the case of a small road where prime cost of installation is often of great importance, small high-speed engines connected by belts to the dynamo are naturally more economical in first cost and in space than the more efficient slow-speed direct-coupled engines and dynamos. Small direct-driven traction plants are rare either in England or America. In large plants the difference in initial cost is amply repaid within a very short space of time by the far cheaper working of large direct-coupled units.

DYNAMOS.—The question as to what type of generator should be used for electric traction is very important. As in the case of engines, railway generators must stand very heavy overloading without damage. Moreover, as one pole is earthed, the greatest care must be taken that the very best insulation is used throughout in their construction. As the loads to which they are subject are extremely variable, dynamos as usually constructed for lighting work would require the position of their brushes to be constantly altered. To obviate this, very heavy magnetic inductions are allowed for in designing these generators, thus rendering it unnecessary to shift the brushes and avoiding sparking. It is nearly universal practice in America to use toothed armatures in railway work.

As to the type of field winding which should be adopted, it would seem from tests made on a large scale, with separately excited, shunt, and compound wound machines by American dynamo manufacturers and engineers, that the best suited to railway work from every point of view is the over-compounded type of generator. The usual pressure of current used on trolley lines in America is 500 volts, and for this tension dynamos are designed in such a manner that at no load the pressure between their terminals is 500 volts, this pressure being increased to 550 volts when the full load comes on. The over-compounding can be regulated up to 10 per cent. by varying a german-silver shunt placed on the series coil.

As it is not intended in this work to go into details of dynamo design, we will only bring out those particular points which have to be taken into consideration when specially studying electric tramway installations. To this end we will describe and illustrate the standard types of electric railway machinery which have been evolved by the large American and Continental manufacturers and designers from the past ten years' practical experience.

CHAPTER XVI.

GENERATORS.

THE General Electric Company of America, which is a combination of the older Thomson-Houston, Brush, Edison, and many smaller companies, manufactures standard types of bipolar generators, some particulars of which are given in Table LXX. This was the first type of machine used in railway practice, running at high speed and generally connected by belting and counter-shafting to the steam engine. In early days, when the special conditions to be fulfilled by railway generators had not been realised by manufacturers or engineers, it was thought that any old machine, which had been constructed for lighting purposes, was good enough for railway work, and breakdowns in railway power stations were therefore extremely numerous. It became necessary for this reason to multiply electrical units as much as possible and to connect them to the engines in such a way that any engine could drive any generator. This accounts for the large number of very small units which are still to be found in early electric traction plants. Now that designers understand the conditions to be met with, accidents to generators are extremely infrequent.

TABLE LXX.—DATA OF GENERAL ELECTRIC COMPANY'S BIPOLAR RAILWAY GENERATORS.

Kilo-watts.	Horse-Power.	Amperes.	Weight in Pounds.	Pulley. Diameter in Inches.	Pulley. Face in Inches.	Pulley. Bore in Inches.	Revolutions per Minute.	Floor Space in Inches.
45	100	90	6,800	17	12	3	1,000	83 × 58
60	200	120	9,790	24	13	$3\frac{1}{4}$	800	$92\frac{1}{2}$ × $62\frac{5}{8}$
100	300	200	16,200	26	16	$3\frac{3}{4}$	650	105 × 68
200	500	00	33,225	44	24	...	450	135 × 92

Table LXXI. gives the dimensions of belted four-pole generators as built by the General Electric Company in America, and the British, German, and French Thomson-Houston Companies in Europe. This is the

standard type of machine for installations having units not exceeding 500 kilowatts. There is no necessity to discuss the reasons why the multipolar is preferable to the bipolar type for large machines. They are universally known, and in all electric installations where large units are used, the multipolar generator is the only accepted type. Fig. 247 gives a very good idea of this type of machine. Some engineers prefer using two generators connected together by clutches and driven by one engine from a pulley situated between the two dynamos. Figs. 248 to 250 show two 300-kilowatt generators of this type. Figs. 251, 252, and 253 give the general dimensions and form of the four-pole 500-kilowatt generator. The frames of these generators, as will be seen from the illustrations, are exceedingly massive. Up to 200 kilowatts, the frame is cast in two parts, the upper half of the field forming one part, while the lower half of the field, together with the base, constitutes the second casting. In the larger sizes the base of the machine is cast in two parts. This is done so that when two of these generators are to be coupled together, the removable section of the base is replaced by a larger casting which supports a large pulley on a separate shaft connected to the armature shafts by friction clutches as shown in Figs. 248, 249, and 250.

TABLE LXXI.—DIMENSIONS OF GENERAL ELECTRIC COMPANY'S BELT-DRIVEN RAILWAY GENERATORS.

Number of Pole-Pieces.	Capacity in Kilowatts.	Revolutions per Minute.	Volts at Full Load.	Weight in Pounds.	Pulley.			Floor Space in Inches.
					Diameter in Inches.	Face in Inches.	Bore in Inches.	
4	100	650	550	11,830	$26\frac{1}{2}$	16	4	76 × 82
4	200	425	550	24,110	41	26	6	73 × 132
4	300	400	550	36,225	$43\frac{3}{8}$	37	$6\frac{1}{2}$	81 × 153
4	500	350	550	61,500	49	56	$7\frac{1}{2}$	95 × 184

Figs. 254 and 255 give a section and side view of the armature of a 150-kilowatt four-pole generator running at 200 revolutions per minute.

The pole-pieces are separate castings, and are bolted to the inside face of the frame. The two parts of the field frame are connected together by long bolts running through the castings from the upper to the lower pole-pieces. The armature of this machine is built up of punched sheet-iron rings insulated from each other by a coat of varnish. These are held together by long iron bolts. The core is supported upon two heavy bronze spiders. The armature is of the drum type, the conductors consisting of

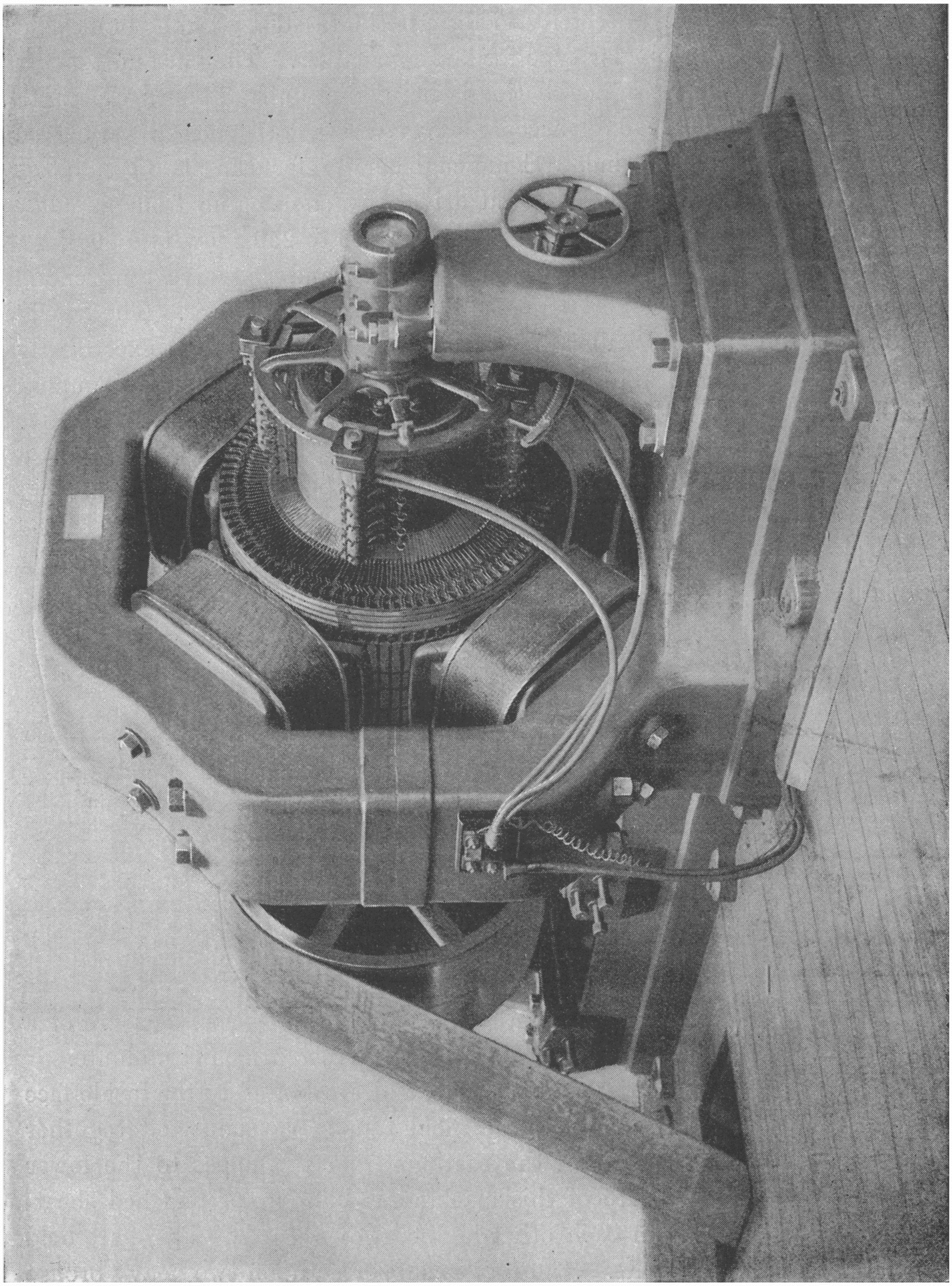
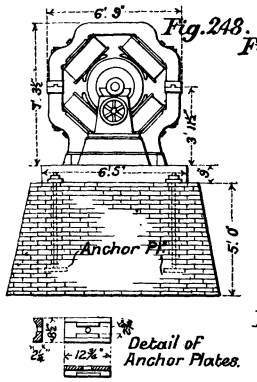


FIG. 247. GENERAL ELECTRIC COMPANY'S MULTIPOLAR RAILWAY GENERATOR.



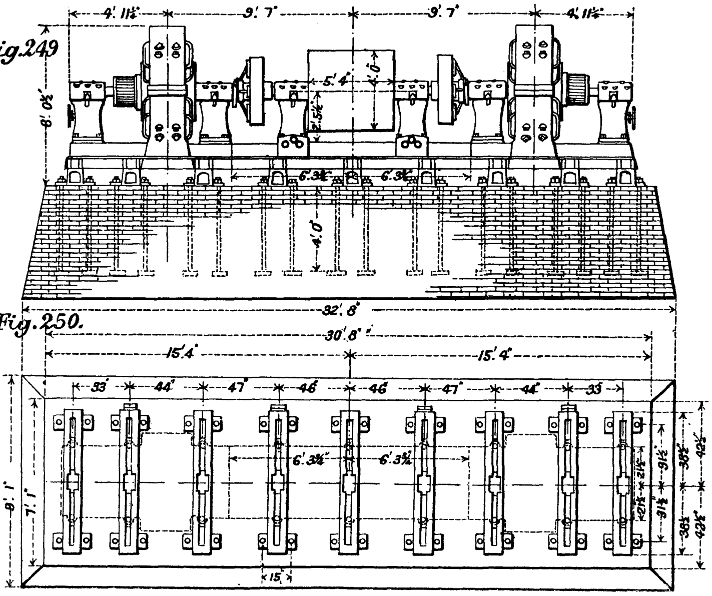
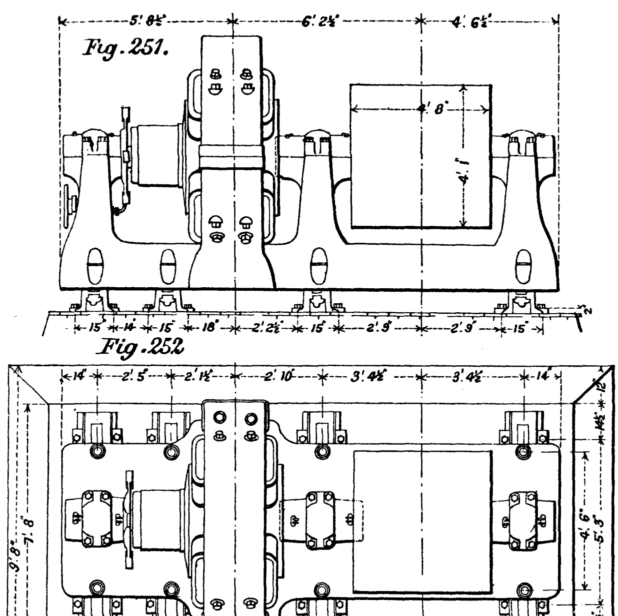
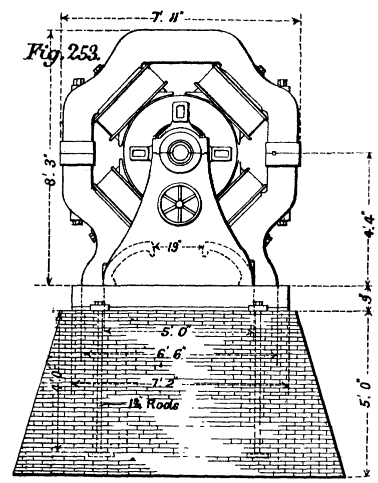


TABLE OF WEIGHTS.	
Two Lower Frames at 12,370	24,740
Six Standards „ 1,030	6,180
Eight Pole Pieces „ 1,425	11,400
Two Upper Frames „ 7,055	14,110
Two Armatures „ 6,920	13,840
Pulley	5,000
Eight Field Spools at 450	3,600

(3024. A.)

General Electric Company's 300-K.W. Multipolar Railway Generator.

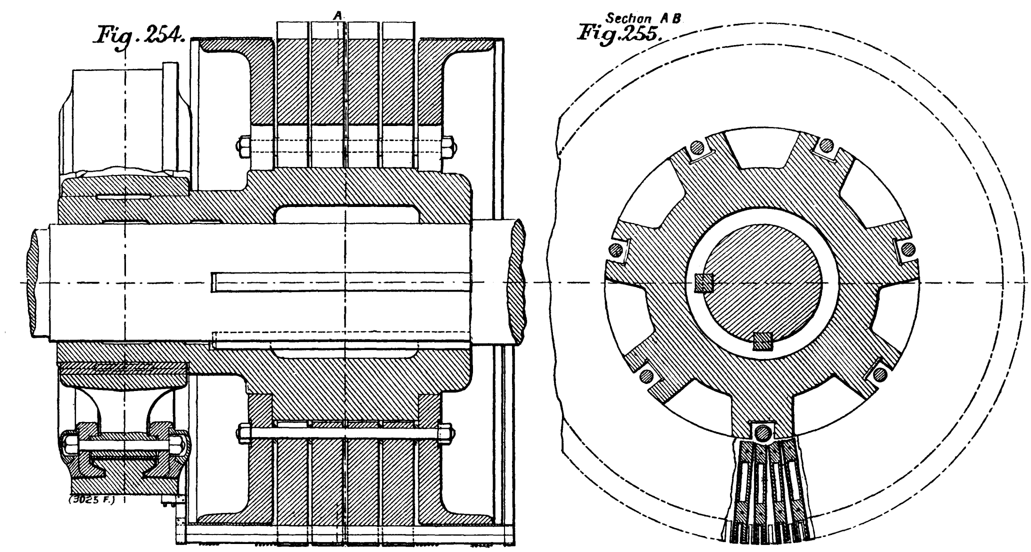




General Electric Company's 500-K.W. Railway Generator.

copper bars insulated by varnished cotton coverings and mica from the sides and bottom of the slots in the armature in which they are placed. These conductors are generally driven in from one end, and prevented from shifting by small wooden wedges driven in over them. As the top of the slots is narrower than the diameter of the bars, no binding wire of any kind is necessary to hold them in place. Fig. 256 shows one of these armatures. In the small sizes of generators the commutator fits directly on to the shaft, but in the larger type it is supported by a bronze spider, leaving an air space between it and the shaft.

The field coils are wound on sheet-iron spools furnished with brass



ARMATURE OF GENERAL ELECTRIC COMPANY'S 150-K.W., 4-POLE RAILWAY GENERATOR.

flanges, which are fitted on to the pole-pieces before these are bolted to the framework. The brush-holder in the larger type consists of a long brass spindle supporting a number of small frames which hold the carbon brushes, and which are fitted with hammer blocks and tension springs. The advantage claimed for this type of brush is that the brushes can be moved to any desired position laterally along the spindle. The number and sizes of carbon brushes used vary with the type of generator. (See Table LXXII.) With generators which have often to run for several days without stopping, cool-running bearings are of the very greatest importance. The bearings used in these generators are on the ball-and-socket principle, and adjust themselves. (See Figs. 257 and 258.)

TABLE LXXII.—NUMBER AND SIZE OF CARBON BRUSHES USED ON FOUR-POLE RAILWAY GENERATORS.

Capacity in Kilowatts.	Number of Brushes.	Size of Carbon Brush in inches.
100	8	$2\frac{1}{4} \times 2\frac{1}{4} \times \frac{5}{8}$
200	10	$2\frac{1}{2} \times 2\frac{1}{4} \times \frac{5}{8}$
300	16	$2\frac{1}{4} \times 2\frac{1}{4} \times \frac{5}{8}$
500	20	$2\frac{1}{4} \times 2\frac{1}{4} \times \frac{5}{8}$

The bearings are lined with babbitt, into which oil-ways are cut.

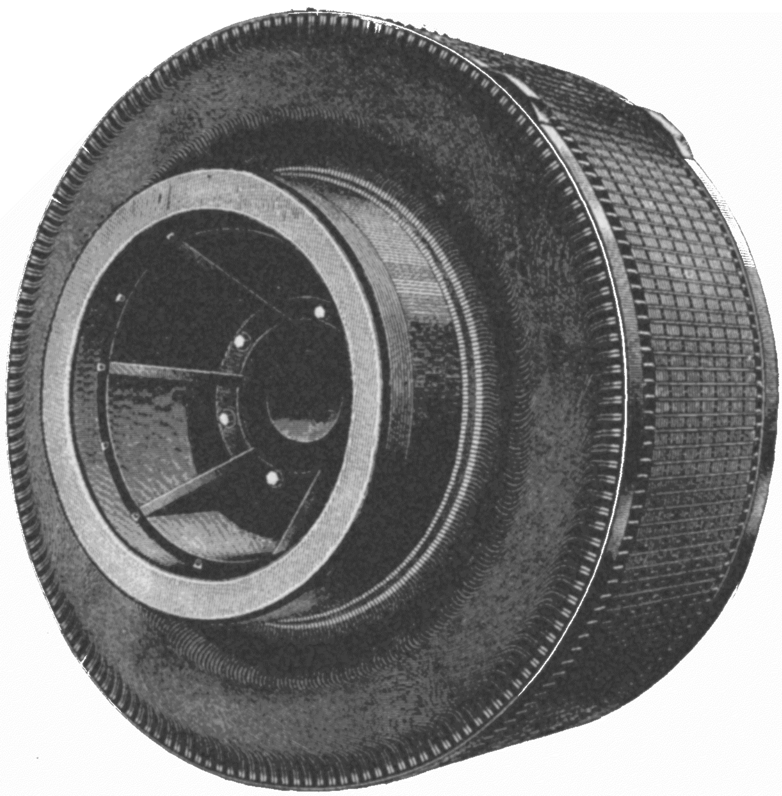


FIG. 256. ARMATURE OF GENERAL ELECTRIC COMPANY'S RAILWAY GENERATOR.

They are supported on cast-iron standards, to which they are bolted at the base. The standard proper and the lower half of the bearing box are cast separately, the upper half of the box making a third casting. The lower half is hemispherical, and fits into the bowl-shaped top of the standard. Long bolts run from inside this standard through ears cast on each side of the box. The holes through which these bolts pass are $\frac{1}{8}$ in. larger in diameter than the bolts themselves, thus allowing considerable play. The

nuts are not screwed down on to the bolts until the armature has been put in place and the bearings have automatically adjusted themselves to the shaft. In all the larger types of generators a third support for the armature shaft is furnished outside the pulley.

The bearings are kept oiled by two brass rings, a method which, for some time past, has been used with the best results in Europe. All the bearing boxes are furnished with glass gauges showing the height of the oil within. The bedplate upon which the generator rests is fitted with a ratchet and screw bolt to tighten up the belt. Railway generators, before being sent out of the shop, are run for eight hours under full load.

Fig. 257.

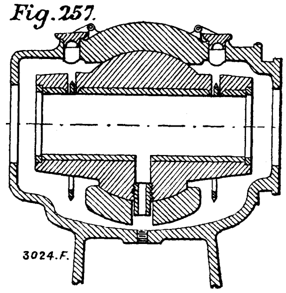
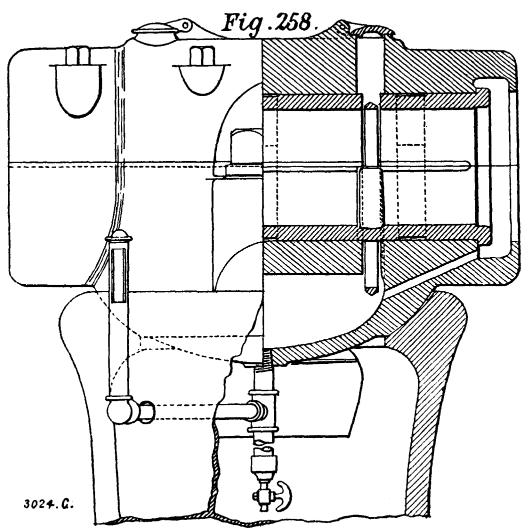


Fig. 258.

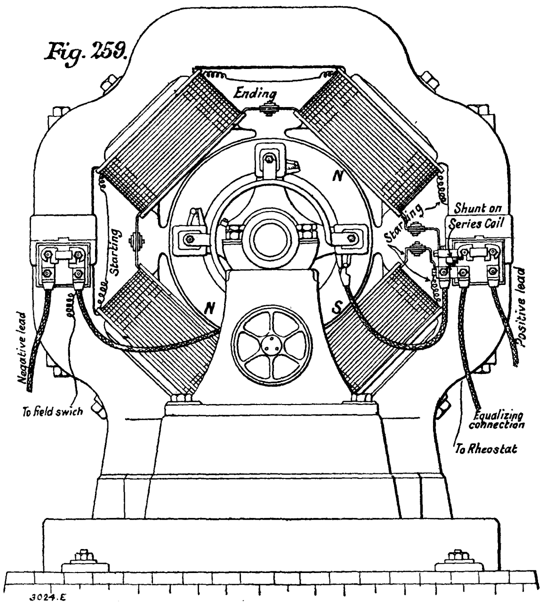


BEARINGS OF GENERAL ELECTRIC COMPANY'S RAILWAY GENERATOR.

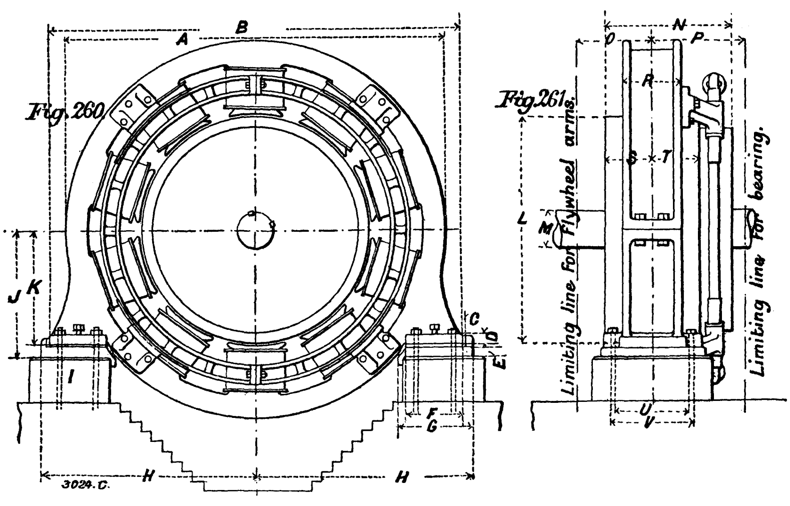
Insulation is tested to stand 3000 volts alternating. The connections between the brushes, which are cross-connected, and the winding of the field magnets are clearly shown in Fig. 259 for the four-pole type of generator.

Table LXXIII. gives the general dimensions of the direct-coupled generators constructed by the General Electric Company of America. The dimensions are given in inches, and apply to diagram Figs. 260 and 261. Till quite recently, direct-coupled generators have found but little favour with American engineers, but in the newest and best designed power-houses in America the use of large multipolar, slow-speed, direct-coupled generators has been adopted to a very large extent, and with the greatest success. In this country, where land is extremely expensive, there seems

little reason to doubt that direct coupling will be largely used in connection with electric traction work. The commercial efficiency of these generators



Connections and Winding of General Electric Company's 4-Pole Railway Generator.



Dimensions of General Electric Company's Direct-Coupled Railway Generators. (See Table LXXIII.)

averages 95 per cent., and the electrical efficiency reaches 98 per cent. These generators run quite cool, their maximum armature temperature being about 72 deg. Fahr. above the surrounding air.

TABLE LXXIII.—General Electric Company. General Dimensions of Direct-Driven Railway Generators.

Poles.	Kilo-watts.	Revo-lutions per Minute.	Form.	Volts.	Weight of Arma-ture.	Weight of Generator Complete.	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	R	S	T	U	V
6	200	120	A	550	14,400	37,300	108½	116	1	3	3	16	22	61	1¾	42½	38½	59¼	9-11½	47⅝	28⅛	31⅞	17½	20⅛	18⅛	29	31½
6	200	150	E	550	13,300	33,600	108½	116	1	3	3	16	22	61	1¾	42½	38½	59¼	9-11½	47⅛	28⅛	31⅞	14½	19⅞	17⅞	29	31½
6	250	150	A	550	16,000	39,900	108½	116	1	3	3	16	22	61	1¾	42½	38½	59¼	11½-13	54⅞	33½	36	18¾	20⅜	21⅜	29	31½
6	250	200	B	550	13,700	34,200	108½	116	1	3	3	16	22	61	1¾	42½	38½	59¼	11½-13	50⅞	31½	34	14½	21⅜	19⅜	29	31½
8	300	100	A	550	28,500	65,300	133¼	155	1	4	4	24	31	81	2	47	42	72	15-18	59 9/16	42	44	21¾	22	22	40	43
8	400	80	A	550	31,900	78,000	133¼	155	1	4	4	24	31	81	2	47	42	72	15-18	67¼	34	49½	25	25	25	40	43
8	400	100	A	550	30,100	71,400	133¼	155	1	4	4	24	31	81	2	47	42	72	15-18	64¼	34	48	25	23½	23½	40	43
8	400	120	A	550	28,900	66,000	..	..	..	..	..	..	..	..	..	..	..	..	15-18	—	—	—	—	—	—	—	—
6	400	150	B	550	19,100	56,800	122½	150	1	4½	4	16	19½	78½	2	30	25	69½	14-16	53	26	43	25	15⅞	15⅞	40	47
6	400	150	C	550	19,100	56,800	122½	150	1	3½	..	16	..	..	2	..	22	69½	14-16	53	26	43	25	15⅞	15⅞	39	
10	500	75	A	550	37,700	96,000	157½	172	1	4	4	24	31	89½	2	53	48	96	16-18	53 13/16	30	38	24	19⅝	19⅝	40	43
10	500	90	A	550	35,100	88,300	157½	172	1	4	4	24	31	89¾	2	53	48	96	16-18	53 13/16	30	38	24	19⅝	19⅝	40	43
10	500	100	A	550	35,100	83,800	157½	172	1	4	4	24	31	89½	2	53	48	96	16-18	53 13/16	30	38	24	19⅝	19⅝	40	43
10	500	125	A	550	33,400	77,000	..	..	..	..	..	..	..	..	..	..	..	..	16-18	—	—	—	—	—	—	—	—
10	800	80	A	550	49,700	121,400	150⅜	177	1	4½	4	24	30	92	2	47	42	94½	19-22	67 7/16	34	51	34	22¾	22¾	50	53
10	800	100	A	550	49,400	110,200	150⅜	177	1	4½	4	24	30	22	2	47	42	94½	19-22	67 7/16	34	51	34	22¾	22¾	50	53
10	800	120	A	550	45,000	100,800	150⅜	177	1	4½	4	24	30	92	2	47	42	94½	19-22	66⅝	30	53½	30	18¾	18¾	46	49
12	1500	75	B	550	82,100	186,700	100½	206	1	5½	3	30	34¾	106	2	65	61	106	24	72 7/16	34⅛	53⅞	36	24⅛	24⅛	54	56
6	200	200	A	550	8,100	23,100	107½	138	1	3	2	16	21	72	1¾	23½	20½	59¼	9-11½	34¾	20	31	11½	9 15/16	9 15/16	20	2

Fig. 262. (Clock wise)

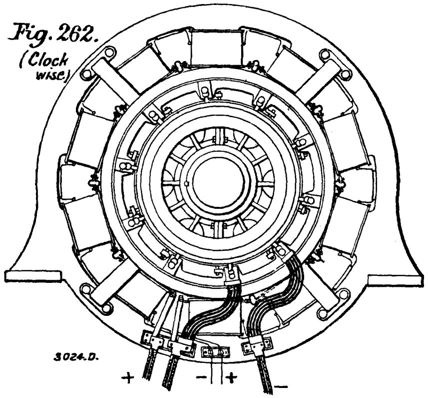


Fig. 263. Counter Clockwise

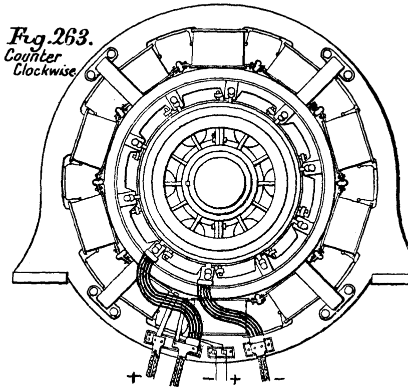
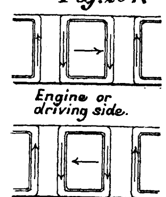
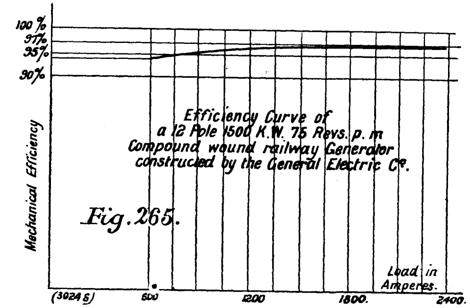


Fig. 264.





Efficiency Curve of a 12 Pole 1500 K.W. 75 Revs. p.m Compound wound railway Generator constructed by the General Electric Co.

Fig. 265.

Connections of 10-Pole, 500-K.W. Railway Generator.

Figs. 262, 263, and 264 show the connections between the brushes and the field-magnet spools for a 10-pole generator of 800 kilowatts running at 115 revolutions per minute. The observer is supposed to be inside of the frame, and looking at the face of the lower pole-piece (Fig. 264). The large arrow indicates the direction of rotation of the lower half of the armature. The small arrows correspond to arrows on the spool flanges, the spools being so placed that the arrows point in opposite directions on each succeeding spool.

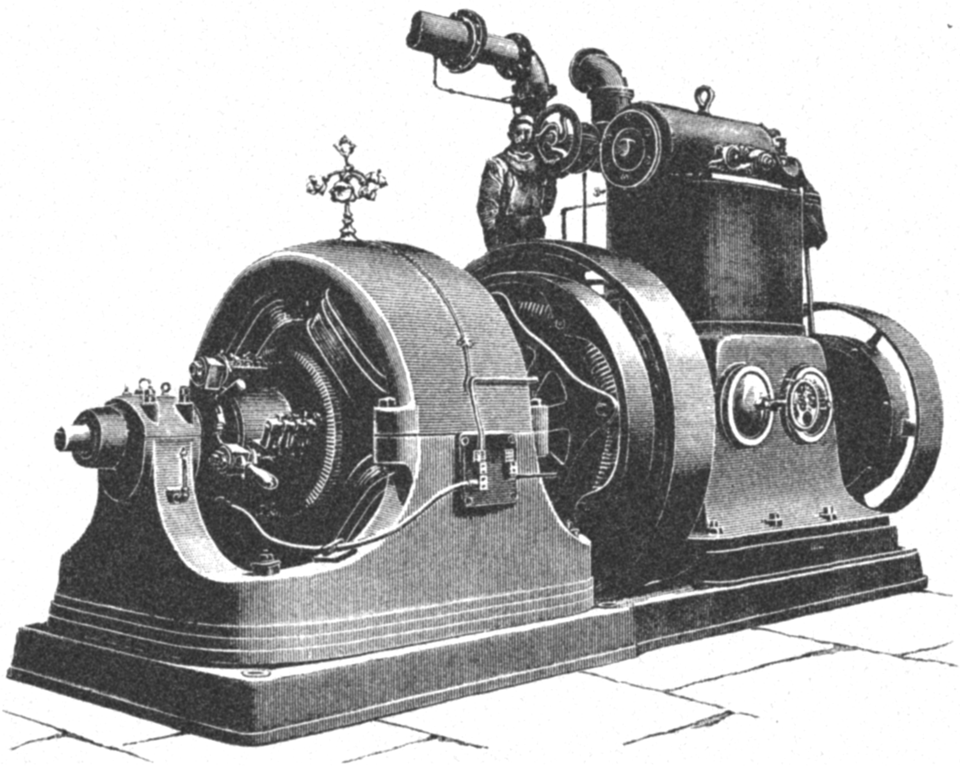


FIG. 266. WESTINGHOUSE 4-POLE DIRECT-COUPLED RAILWAY GENERATOR.

At the Brooklyn City Railway power station 2,000 horse-power generators have been erected. These are so large that they were put together and wound *in situ*. The first of these large direct-coupled multipolar railway generators was built by the General Electric Company to run the Intramural Electric Railway at the Columbian Exhibition of 1893. It was built after the designs of Mr. H. F. Parshall. The generator is rated at 1,500 kilowatts, has 12 poles, and revolves at a speed of 75 revolutions per minute. At 600 volts it will carry a full load of 2,500 amperes without

heating more than 33 deg. Cent. above the surrounding atmosphere. The dynamo has been so designed that it will stand sudden variations of load equal to the total of its capacity, without sparking, and it will bear 50 per cent overloading for several hours without dangerous heating or sparking. When the first machine was built it was found impracticable to put it together in the works, and it was shipped in pieces to Chicago, where it was erected. When tested, it was found to comply completely with the specification. The whole machine, with the exception of the cast-steel

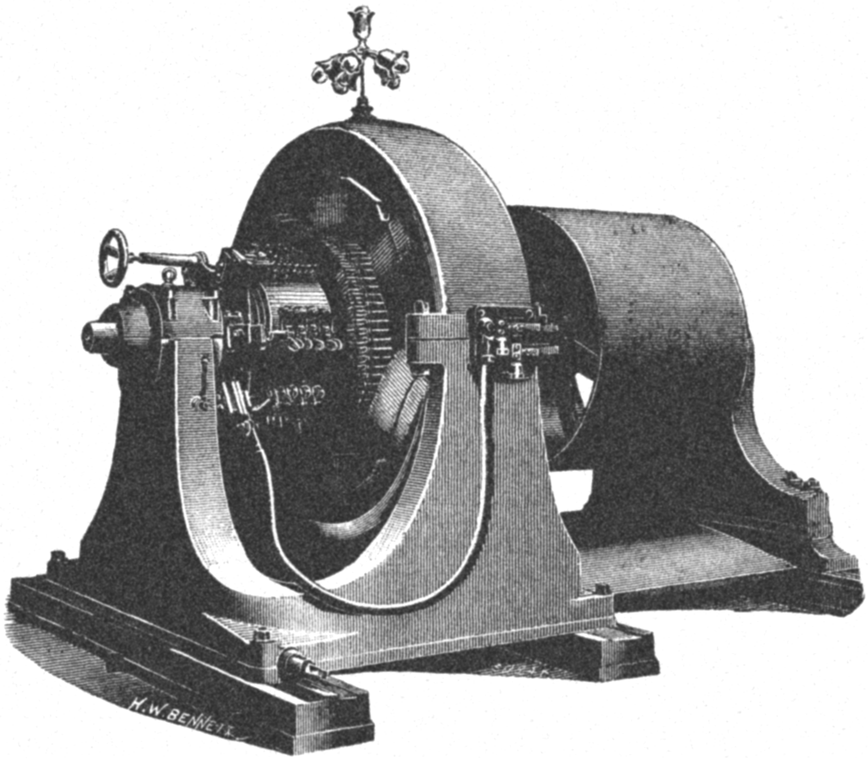
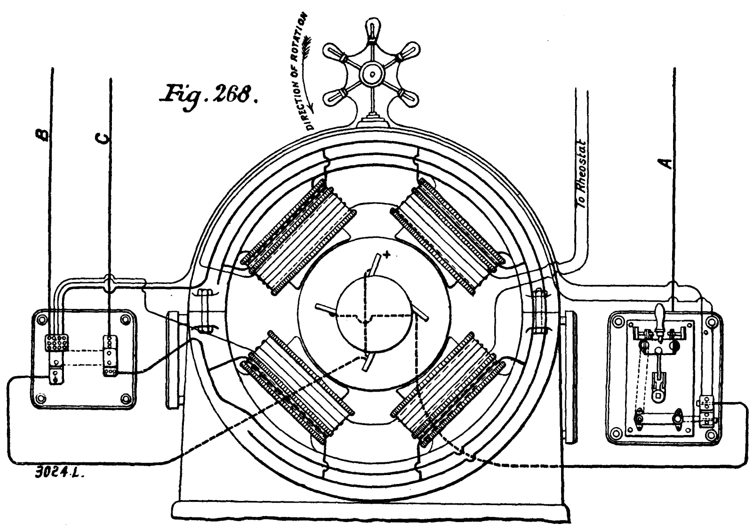


FIG. 267. WESTINGHOUSE 6-POLE RAILWAY GENERATOR.

spider for supporting the armature, which was made by the E. P. Allis Company, of Milwaukee, was constructed at the General Electric Company's Schenectady Works. The diameter of the armature is 126 in., its face is 36 in. wide. There are 336 slots in the armature, in each of which there are four conductors. The sectional area of these conductors is .1875 square inch, and the approximate current density is 1,000 amperes per square inch. The commutator is composed of 58 segments per pole, each one being 3 in. deep and 24 in. long. The diameter of the commutator is 7 ft. The

armature spider is of cast iron, has 12 spokes, and its hub is cast in three parts, over which steel rings are shrunk. The laminated iron discs forming the core are composed of segmental pieces dovetailed into the centre hub. The commutator is so designed that the bars composing it can expand freely lengthwise without injury to the insulation. The clamping rings which hold the segments in place are subdivided, and so arranged that any one segment can be removed, and its commutator bars taken out without displacing any of the others. The air-gap between armature and pole-pieces is $\frac{1}{2}$ in. The weight of copper in the armature amounts to nearly 7,000 lb.

The feeder magnets are of mild cast steel, and have 8,000 ampere turns



CONNECTIONS OF WESTINGHOUSE 4-POLE RAILWAY GENERATOR.

in the shunt coil on each pole, and from six to eight in the series coil, according to the amount of over-compounding desired. The length of the field magnet is 18 in., and the average length per turn, 92.84 in. The series winding is composed of copper strip, the cross-section of which is $3\frac{1}{2}$ square inches. At a tension of 600 volts the magnetic induction in the magnet cores is 90,000 C.G.S. units per square inch, and that in the yoke about 80,000. Carbon brushes are used throughout, and their number is such that the current density in them does not exceed 35 amperes per square inch. As shown in Fig. 265, the efficiency curve of these machines is very flat, thus rendering their use economical in railway power stations.

The resistance of the shunt winding is 54.7 ohms at 60 deg. Cent. The resistance of the series coil is .0013 ohm, and the resistance of the

armature at the same temperature is .004 ohm. It is found in practice that the average tilt forward of lead of the brushes is nearly 20 deg. It speaks well for the design and workmanship of these very large direct-coupled generators, which are constantly liable to heavy overloading, that although a great number of them have been running for nearly two years, they have more than fulfilled the hopes and expectations of their designer and of the

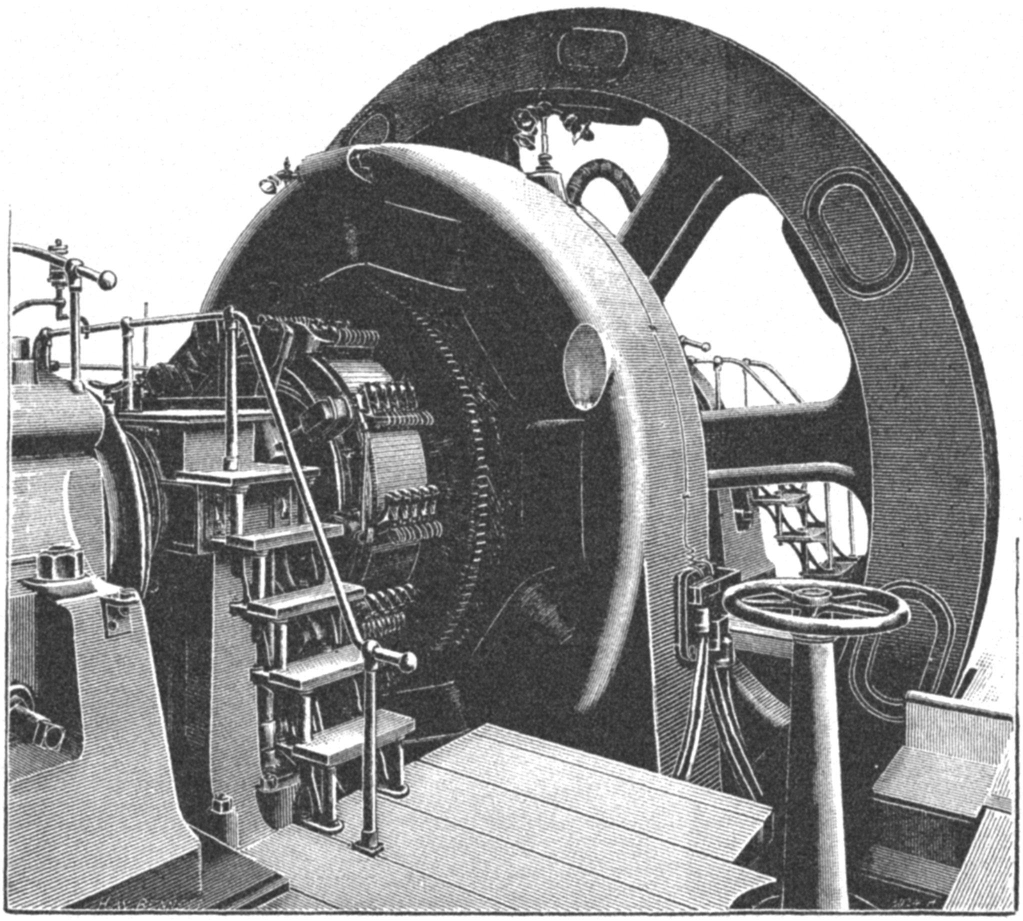


FIG. 269. WESTINGHOUSE 10-POLE DIRECT-COUPLED RAILWAY GENERATOR.

great traction company which operates them. As a proof of their economy, we may mention that in the Brooklyn City Railway Company's power house, where some six of these generators are running, coupled direct to triple-expansion condensing Allis-Corliss engines, the amount of coal consumed per electric horse-power hour furnished at the switchboard is only 1.8 lb.

Westinghouse Electric and Manufacturing Company of Pittsburgh, Pa., U.S.A.—This company has for a long time past manufactured street-railway generators. These dynamos, as a rule, are wound for 500 volts. They are furnished with a rheostat in their field circuit, so that the potential can be raised to 600 volts, and they are designed with a view of bearing 50 per cent. overload without injury for a short time. Table LXXIV. gives

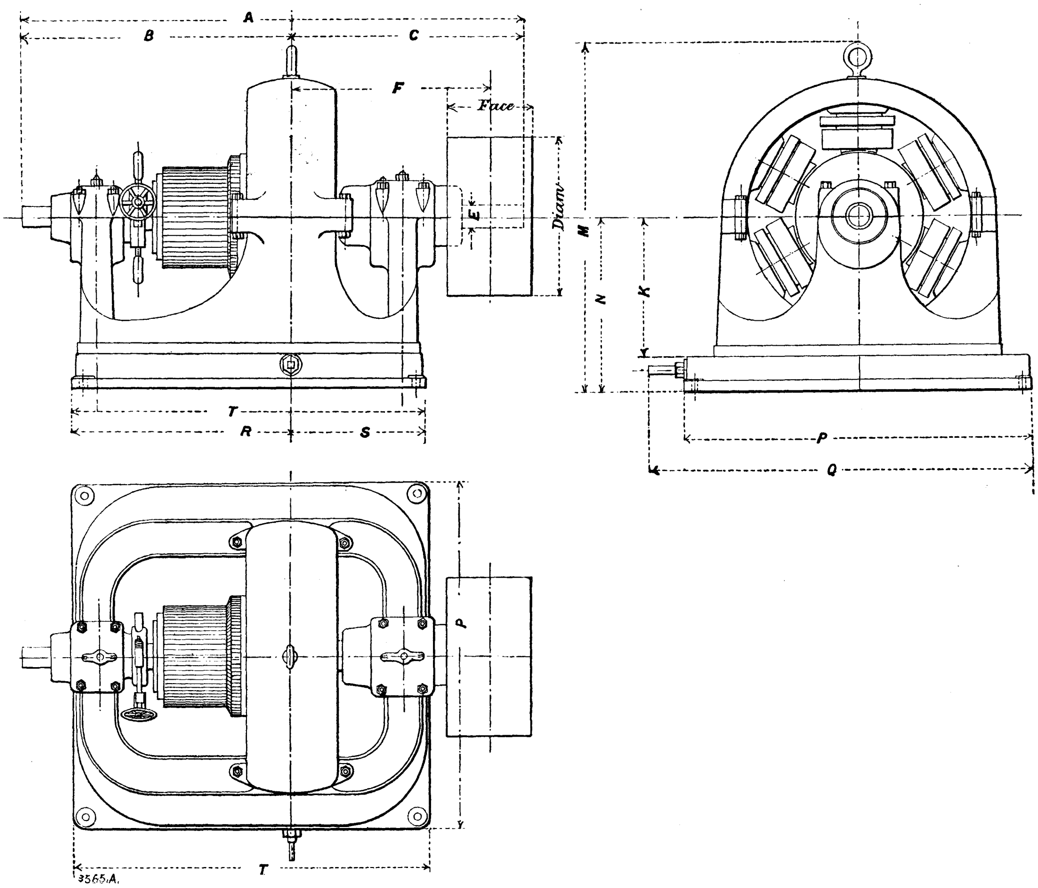


Fig. 270. Westinghouse 2-Bearing Railway Generator.

some interesting data of the generators manufactured by this company. Fig. 266 shows a four-pole generator directly connected to a Westinghouse high-speed engine. Fig. 267 shows one of the latest type of six-pole belt ring railway generators manufactured by the company. This dynamo is mounted on rails, upon which it can be made to slide by a screw. The handwheel shown over the commutator is for shifting the brush-holder. This machine, in common with all large belt driven generators, has three

bearings. These bearings are of the ball-and-socket type already described in connection with the General Electric Company's apparatus. The armatures of these machines are composed of stamped iron discs, punched round a circumference with oval holes. Through these grooves, tubes of insulated material are passed, and in these the stranded armature windings are placed. The field of this generator is cast in two parts, the lower section being cast

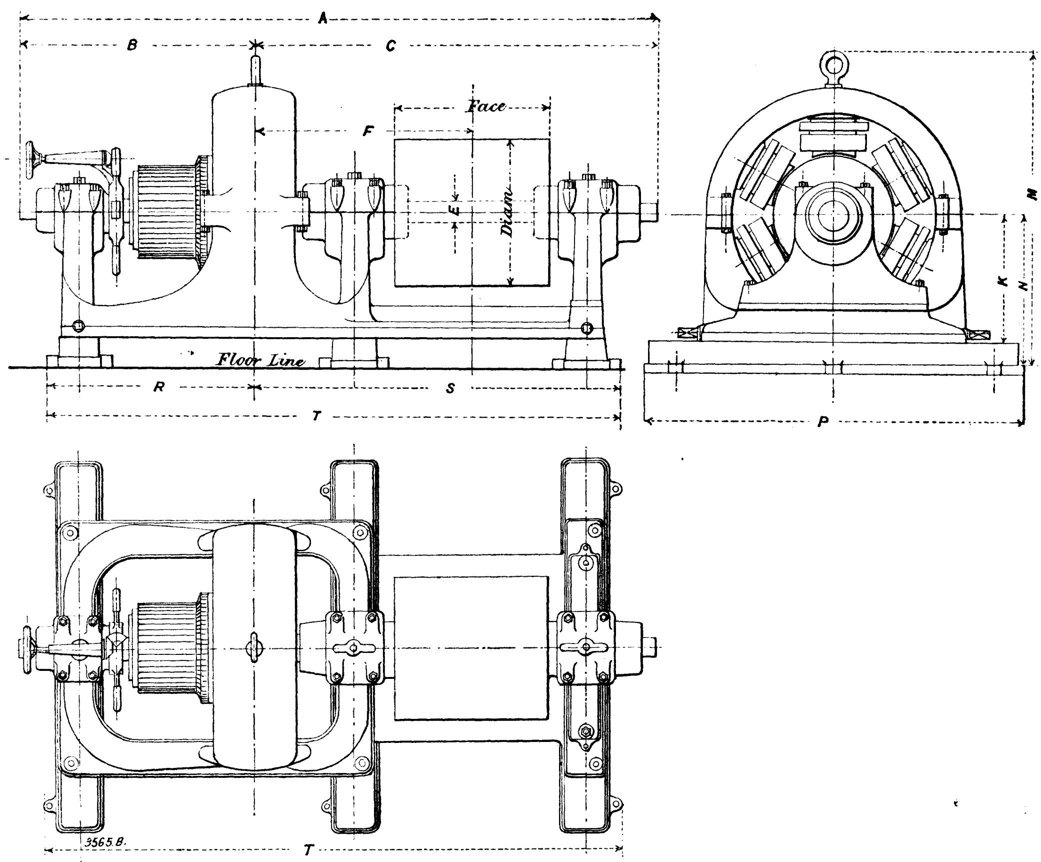


FIG. 271. WESTINGHOUSE 3-BEARING RAILWAY GENERATOR.

in one with one of the standards supporting the bearing. The pole-pieces are cast in one with the field. Fig. 268 shows the connections of field spools. The generator is supposed to be be seen from the pulley end. The shunt coils are connected in series with each other. The four series coils are connected in parallel. A and C are the main leads, and B goes to the equalising bus bar on the switchboard. The brush-holders are cross-connected. The connections of the six-pole generator are practically the

same, the only difference being that there are three pairs of poles and brushes instead of two.

TABLE LXXIV.—Data of Westinghouse Belt-Driven Multipolar Railway Generators.

Horse-Power.	Amperes.	Volts.	Length of Shaft.		Width of Bed-plate.		Height over Eye-bolt.		Diameter of Pulley.	Face of Pulley.	Speed. Revolutions per Minute.	Weight in Pounds.
			ft.	in.	ft.	in.	ft.	in.	in.	in.		
80	120	500	0	72	0	$58\frac{1}{2}$	4	11	26	10	750	8,809
100	150	500	0	$87\frac{1}{2}$	0	$64\frac{1}{4}$	5	4	26	14	750	12,000
150	225	500	0	$92\frac{1}{4}$	5	8	5	9	30	16	625	16,500
250	375	500	8	$10\frac{1}{2}$	6	$2\frac{1}{2}$	6	2	34	28	535	21,150
300	450	500	11	8	6	6	6	11	37	32	500	35,000
400	600	500	13	4	6	9	7	5	40	40	465	38,000
500	750	500	14	$4\frac{1}{2}$	7	$11\frac{1}{4}$	7	6	48	48	375	64,800
700	1,050	500	15	2	8	3	8	9	60	56	300	70,100

Table LXXV. contains some data of the smaller sizes of direct-driven generators constructed by the Westinghouse Company. Fig. 269 gives a very good idea of an extremely handsome 1,500 horse-power direct-coupled generator built for the Philadelphia Traction Company. The armature is mounted directly on the shaft of a Corliss twin tandem compound condensing engine running at 80 revolutions per minute. The generator is compound wound, has ten poles and ten sets of brushes, the alternate brushes being connected in parallel.

TABLE LXXV.—Data of Westinghouse Direct-Connected Railway Generators.

Horse-Power.	Amperes.	Volts.	Length of Shaft.		Width of Bedplate.		Height over Eyebolt.		Speed. Revolutions per Minute.	Weight in Pounds.
			ft.	in.	ft.	in.	ft.	in.		
100	150	500	0	$89\frac{3}{8}$	5	5	6	$2\frac{1}{2}$	300	14,000
160	240	500	0	$99\frac{3}{16}$	5	7	6	9	300	18,800
270	405	500	9	4	7	$0\frac{1}{2}$	7	$11\frac{1}{2}$	250	33,100
500	750	500	9	10	8	8	9	0	215	61,500

The following Tables give the output, approximate speed, and principal dimensions of each of the standard sizes of generators :

TABLE LXXVI.—DIMENSIONS OF 6-POLE, 2-BEARING WESTINGHOUSE DIRECT-CURRENT RAILWAY GENERATORS. (See Fig. 270.)

KW.	Amp.	R.P.M.	A	B	C	E	F	K	M	N	P	Q	R	S	T	Pulley.			Key-Way in Shaft.		Weight (net lb.).
																Diam.	Face.	Length of Hub.	Width	Depth	
			ft. in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	
100	182	650	0 $85\frac{3}{16}$	$43\frac{7}{8}$	$41\frac{5}{16}$	$3\frac{7}{8}$	$35\frac{7}{8}$	24	$61\frac{1}{8}$	30	61	67	$34\frac{5}{8}$	$23\frac{7}{8}$	$58\frac{1}{2}$	28	18	10	$\frac{7}{8}$	$\frac{3}{8}$	9,400
150	273	550	0 $96\frac{1}{4}$	$48\frac{1}{3}$	$48\frac{1}{3}$	$4\frac{3}{4}$	39	29	$70\frac{1}{4}$	35	$75\frac{1}{2}$	81	$38\frac{7}{8}$	$25\frac{3}{8}$	$64\frac{1}{4}$	34	26	16	1	$\frac{3}{8}$	14,000
200	364	510	9 2	$50\frac{3}{4}$	$59\frac{1}{4}$	$5\frac{7}{8}$	$47\frac{1}{2}$	$32\frac{1}{2}$	$77\frac{3}{4}$	$38\frac{1}{2}$	82	$87\frac{1}{2}$	$43\frac{7}{8}$	$29\frac{1}{8}$	73	35	33	20	$1\frac{9}{16}$	$\frac{9}{16}$	19,730

TABLE LXXVII.—DIMENSIONS OF 6-POLE, 3-BEARING WESTINGHOUSE DIRECT-CURRENT RAILWAY GENERATORS. (See Fig. 271.)

KW.	Amp.	R.P.M.	A	B	C	E	F	K	M	N	P	R	S	T	Pulley.			Key-Way in Shaft.		Weight (net lb.).
															Diam.	Face.	Length of Hub.	Width	Depth	
			ft. in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	ft. in.	in.	in.	in.	in.	in.	
250	455	450	12 $4\frac{1}{4}$	$54\frac{5}{8}$	$93\frac{5}{8}$	$6\frac{1}{2}$	$50\frac{1}{2}$	39	88	46	98	$49\frac{1}{4}$	$88\frac{1}{4}$	11 $5\frac{1}{2}$	38	42	32	$1\frac{9}{16}$	$\frac{9}{16}$	24,750
500	910	320	15 $8\frac{3}{4}$	$65\frac{1}{2}$	$123\frac{1}{4}$	$8\frac{1}{2}$	$67\frac{1}{4}$	54	$119\frac{1}{8}$	61	$123\frac{1}{2}$	61	$118\frac{3}{4}$	14 $11\frac{3}{4}$	60	64	42	$2\frac{1}{8}$	$\frac{5}{8}$	46,000

TABLE LXXVIII.—GIVING DETAILS OF WESTINGHOUSE DIRECT-CONNECTED SLOW-SPEED RAILWAY GENERATORS.

Horse-Power.	Kilowatts.	Amperes.	Volts.	Speed, R.P.M.	Total Weight in Pounds.
335	250	455	550	90 to 100	40,000
536	400	727	550	90 „ 100	60,000
670	500	910	550	85 „ 90	90,000
1,072	800	1,454	550	80 „ 85	125,000
1,506	1,125	2,046	550	75	195,000
2,010	1,500	2,730	550	75	240,000

TABLE LXXIX.—GIVING DETAILS OF WESTINGHOUSE HIGH-SPEED DIRECT-CONNECTED RAILWAY GENERATORS.

Horse-Power.	Kilowatts.	Amperes.	Volts.	Speed, R.P.M.	Total Weight in Pounds
134	100	182	550	250	11,000
200	150	273	550	180 to 200	25,000
268	200	364	550	170 „ 185	35,000
335	250	455	550	155 „ 170	37,000
402	300	546	550	145 „ 160	45,000
502	375	682	550	130 „ 142	51,450

The field magnets are composed of laminated wrought-iron, and are cast into the framework. The fields are divided laterally, and are bolted together top and bottom. Both halves of the fields slide back on cast-iron

rails to form part of the main bedplate, being brought back by means of screws. By this means it is easy to remove a field coil if required, besides which access to the surface of the armature may be gained.

The brush-holders are mechanically connected to ten arms radiating from a cast-iron ring, this ring being supported by a pedestal placed between one of the main engine bearings and the commutator of the dynamo. The adjustment of the brushes is made by a handwheel gear by means of a worm and wormwheel to the brush-holder yoke. The brushes

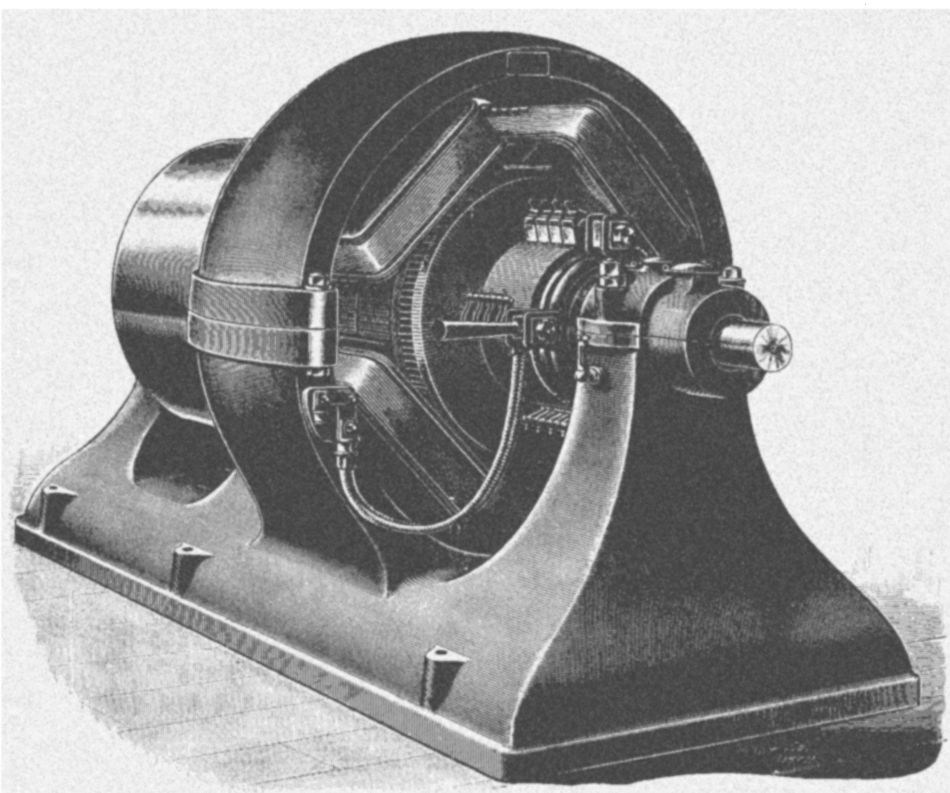


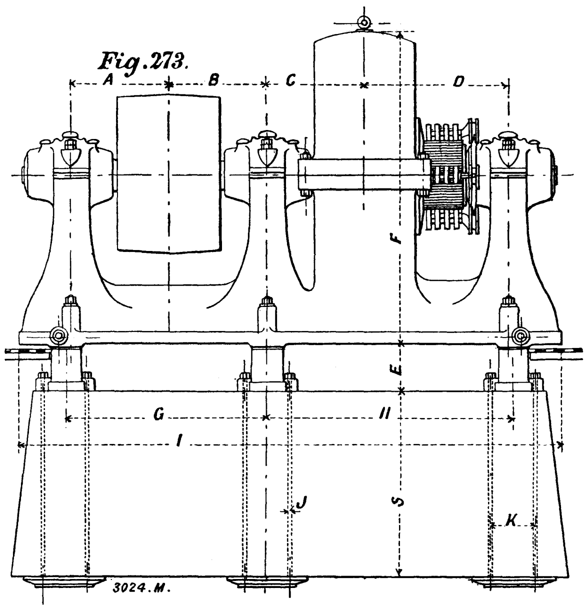
Fig. 272. Walker 4-Pole Railway Generator.

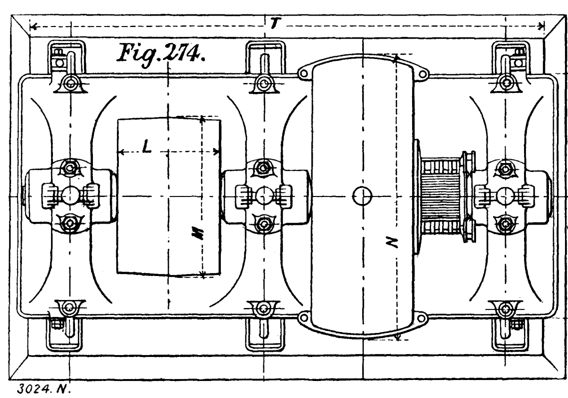
are of carbon, as universal practice in traction work teaches that these are the best.

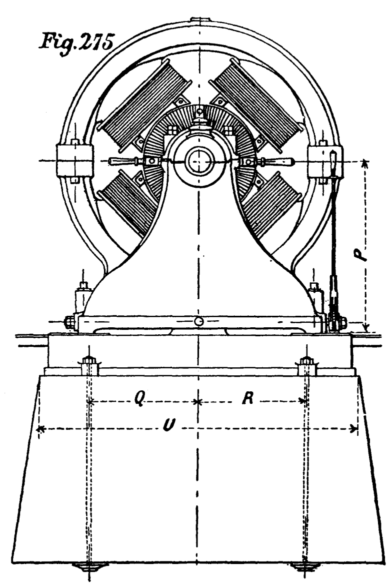
Each coil of the armature is separately wound in a lathe and insulated before being placed and fixed between the teeth of the armature.

The series coils of the field are composed of flat copper strips forged to shape and then specially insulated. The generator is over-compounded, so that at full load the electromotive force is increased by about 5 per cent.

The Walker Manufacturing Company.—Table LXXX. gives data of a belted railway generator as constructed by the Walker Manufacturing Company of Cleveland, Ohio (see Figs. 272 to 275). It resembles in many points the machines already described, and need not be gone into



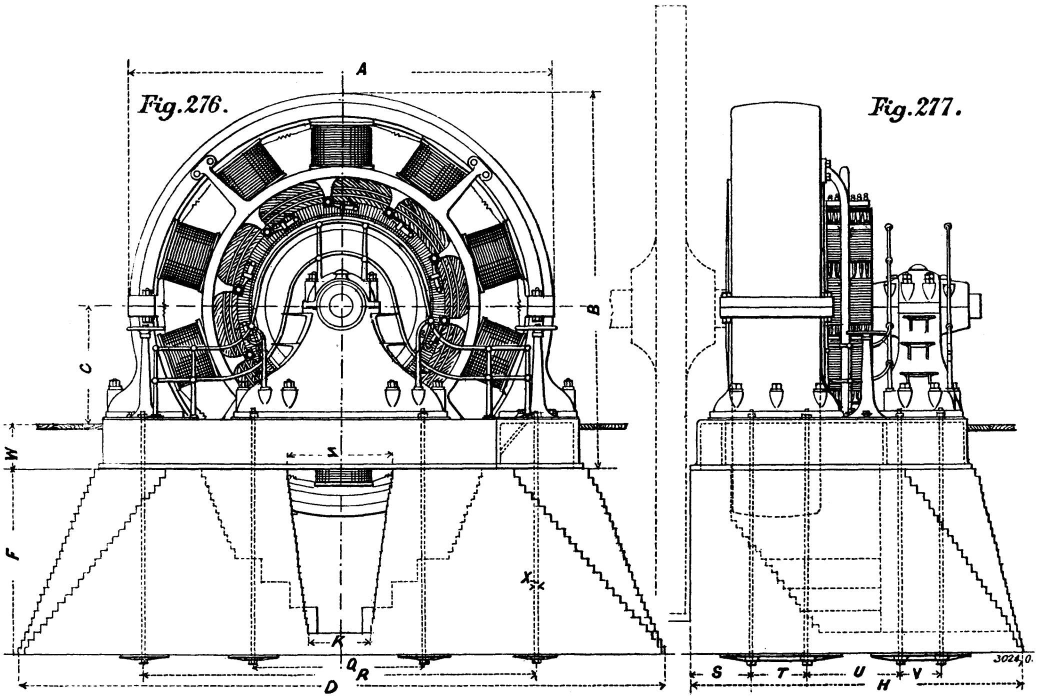


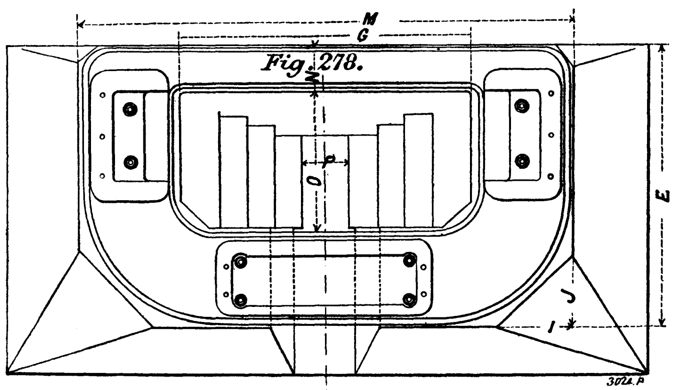


Walker Belt-Driven Railway Generators. (See Table LXVI.)

more fully. Table LXXXI. gives data and dimensions of the direct-coupled generators built by this company (see Figs. 276 to 278).

The Maschinenfabrik Oerlikon, of Zurich.—The Maschinenfabrik Oerlikon, of Zurich, has constructed some very interesting traction plants. Table LXXXII. gives some data relative to their power generators.





WALKER DIRECT-COUPLED RAILWAY GENERATORS. (See Table LXVII.)

TABLE LXXX.—DATA OF WALKER BELTED RAILWAY GENERATORS.

Horse-Power.	Kilo-watts.	Speed in Revolutions per Minute.	Weight in Pounds.	Dimensions in Inches.																				
				A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S*	T	U
335	250	475	30,000	24½	24½	24	36	10	77¼	50¼	61¼	135	1¾	11½	26	40	69	61¼	42	30⅛	30⅛	72	175	84
435	325	425	41,000	28½	28½	26	40	11½	80	55	67	145	1¾	13	35	42	76	63	42	30½	30½	72	190	90
536	400	400	50,000	33½	33½	28½	46	12	82	65	74½	168	1¾	14	40	45	78	64	42	31¾	31¾	84	205	98
670	500	350	65,000	37½	37½	33	50½	14	88	74	84½	185	2	15	50	52	86	68	45	33¾	33¾	96	230	105
805	600	300	76,000	43½	43½	34	53½	15	93	85	86	206½	2	16½	54	60	88	69	48	36	36	96	245	110

* Minimum.

TABLE LXXXI.—Data of Walker Direct-Coupled Railway Generators.

Horse-Power.	Kilowatts.	Speed in Revolutions per Minute.	Weight in Pounds.	Dimensions in Inches.																							
				A	B	C	D	E	F*	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
670	500	120	95,000	111	90	37	170	68	84	82	85	20	20	24	36	130	12	36	15	40	100	15	12	18	10	11	2
805	600	100	110,000	120	100	37	180	77	84	95	100	21	26	24	36	140	12	40	16	49	110	15	12	18	12	12	2¼
1,000	750	90	127,000	136	115	37	206	86	96	106	121	23	28	24	36	168	15	47	17	56	125	20	18½	33	14	13½	2¼
1,340	1,000	80	170,000	152	128	41	228	96	96	118	136	26	31	24	38	188	17½	52	18	62½	139	22½	21	36½	15	14½	2½
2,000	1,500	75	220,000	174	148	48	264	110	96	136	156	30	36	26	40	216	20	60	20	72	160	26	24	42	18	17	2½
2,668	2,000	70	280,000	210	171	57	322	132	96	163	187	36	43	26	40	259	24	72	24	86	192	31	29	50	21½	20	3

* Minimum.

TABLE LXXXII.—Data of Oerlikon Railway Generators.

Horse-Power.	Kilowatts.	Volts.	Amperes.	Revolutions per Minute.	Weight in Pounds.
70	33	550	60	700	4,409
66	44	550	80	600	7,275
82	55	550	98	500	9,038
97	66	550	123	450	11,684
130	88	550	160	400	15,432
160	110	550	200	350	23,148
200	135	550	250	300	25,353
300	200	550	364	300	37,478

CHAPTER XVII.

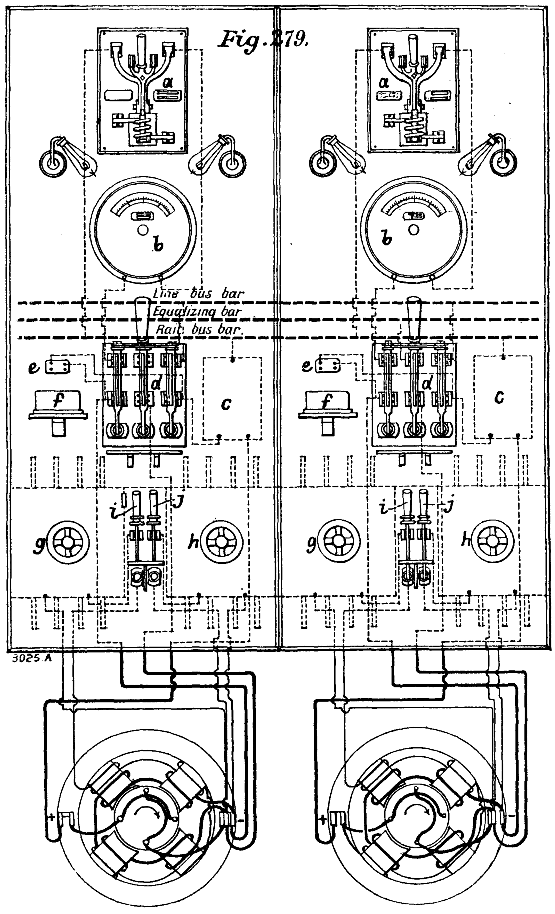
SWITCHBOARDS.

THE method of coupling and connecting the generators to the main switchboard and connecting up to the various feeders, differs according to whether the generators used are shunt, compound wound, or separately excited, and whether accumulators are used or not. The switching arrangements are also slightly different when the two- or three-wire system is used.

The ordinary method of employing compound-wound machines in parallel on the two-wire system is generally used at present, although it seems probable that the three-wire system will soon find great acceptance. In America it is customary to standardise switchboards in panels, each panel having the various instruments and switches fixed to it and suited to a given size of generator. These panels are generally arranged in such a way that a series of them can be put side by side, and thus form one large switchboard. In small lines where there are but few generators and feeders, the wires from both generally come to one panel or switchboard. The connections of such a board are shown in Fig. 279, where *a* is the automatic circuit-breaker which springs out when the current exceeds a certain strength for which the circuit-breaker has been previously set; *b* is the ammeter, *c* the lightning arrester, *d* the main switch which cuts off simultaneously the line, the equalising and the bus bars from the generators *e* is the place into which the voltmeter plug is inserted when it is desired to ascertain the voltage of the line; *f* is the bracket on which the voltmeter is placed when in use; *g* is the rheostat placed in series with the shunt field, and destined to regulate the difference of potential between the brushes; *h* is the rheostat put as a shunt on the series winding of the generator, and which serves to regulate the over-compounding of the same; *i* is a switch serving to cut the rheostat out of the shunt field, and *j* cuts the shunt out of the series field.

In large stations having a great number of feeders and large generators it becomes advisable to entirely separate the main switchboard from the feeder board. Fig. 280 is a diagrammatic representation of the switch-

board connections generally adopted by the General Electric Company of America in connecting up compound-wound generators. The switch A in this diagram occupies three positions. It is set in the first position when a generator is switched on or off the circuit, and it puts six 100-volt lamps in series, or an equivalent resistance coil, into parallel with the shunt winding of the generator. These lamps serve to take off the extra current which



Connections of Railway Switchboard.

arises when the generator is switched on or off, and which is due to the self-induction of the shunt winding. When one generator is already running and a second one is put in parallel with it, the second machine is excited by the main current before the generator is put in parallel on the circuit. This is done by moving the switch A from the first to the third position. When a generator is switched off the circuit, its shunt winding

is also switched off simultaneously with the generator. The rest of the diagram is self-explanatory. Figs. 281 and 282 show the front and rear view of one of the General Electric Company's switchboards. The two panels on the left-hand side in the front view are the main switchboard panels. The three panels on the right hand are the feeder panels. At the top of the panels are placed the circuit-breakers, under these the rheostat, field switch, and pilot lamp, and lower again the positive, negative, and

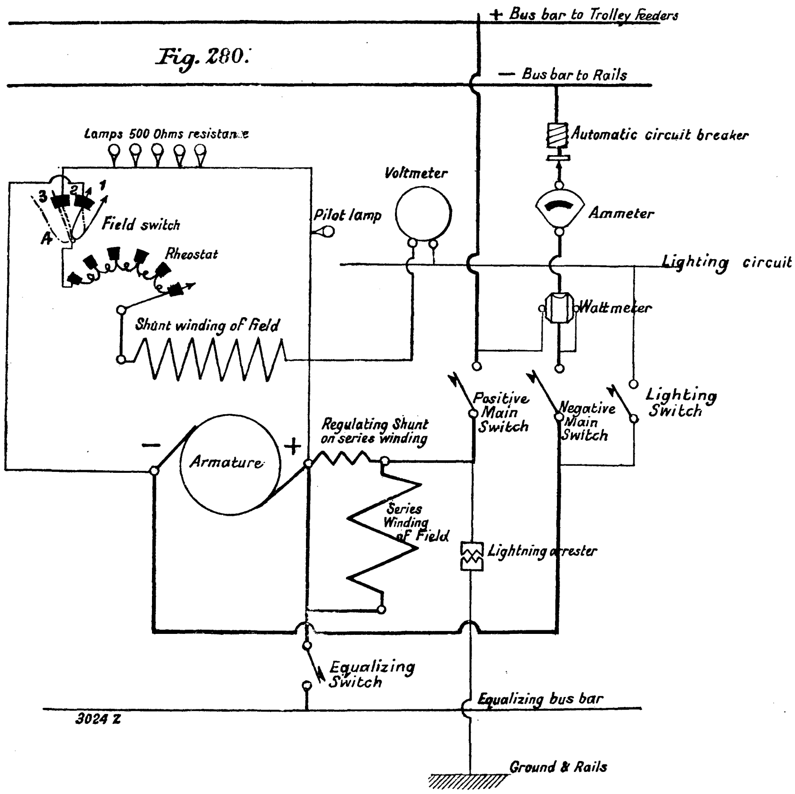


DIAGRAM OF GENERAL ELECTRIC COMPANY'S SWITCHBOARD CONNECTIONS FOR COMPOUND-WOUND RAILWAY GENERATORS.

station lighting main switches. The middle panel serves to sustain a registering wattmeter and main ammeters through which the current of all the generators passes. On the upper left-hand corner the main voltmeter is placed, which, by means of a plug and flexible wire, can be connected to any of the generators.

The latest practice tends towards putting the equalising switch on a separate column next to the generators. Such columns and switches are

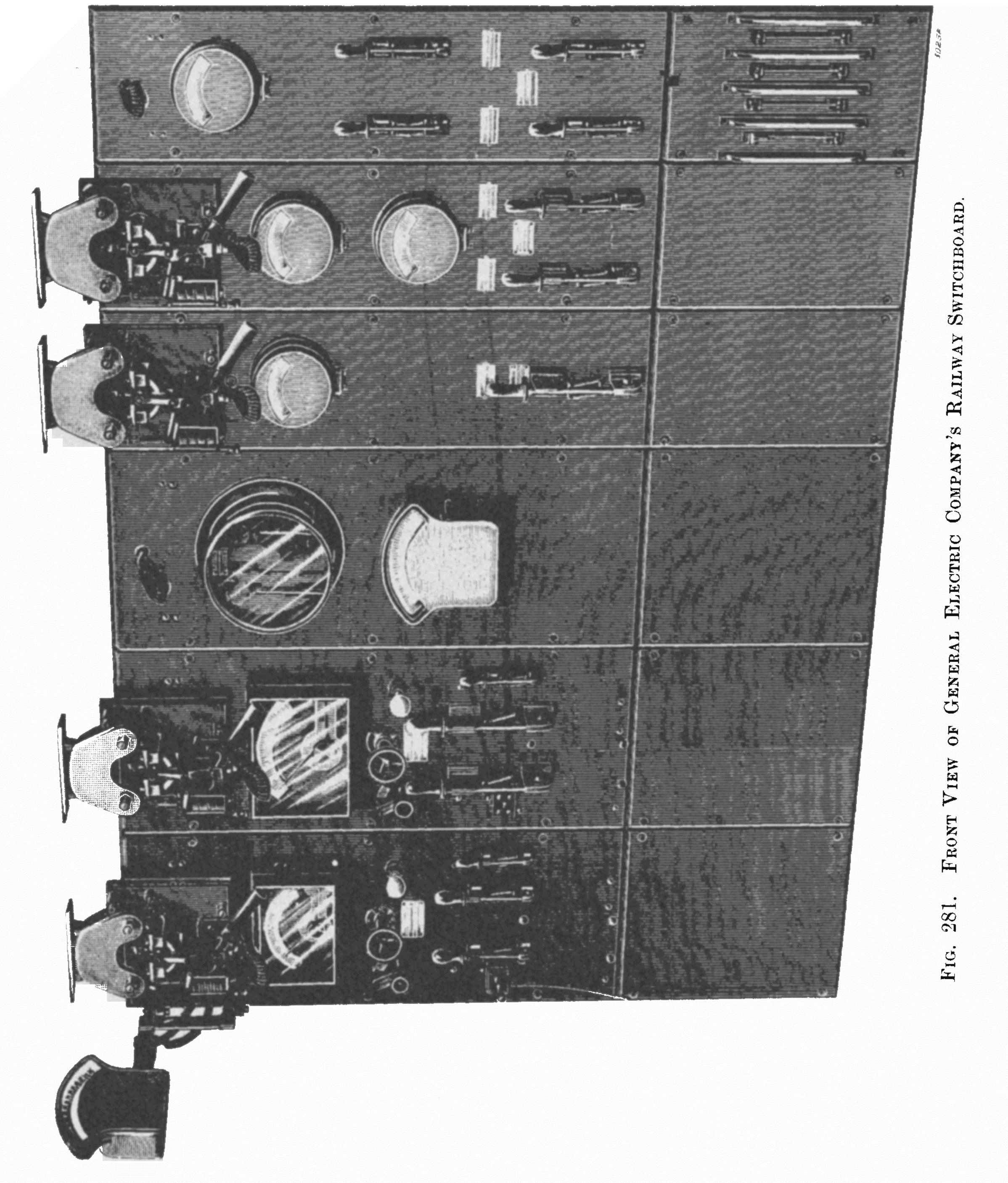


Fig. 281. Front View of General Electric Company's Railway Switchboard.

shown in Fig. 283. In very large stations it has been found a very good arrangement to place a main switchboard vertically against the wall overlooking the power-house, and a few feet from it and in an inclined position the feeder switchboard. One man is constantly kept at the switchboard, and can thus easily watch and work all the instruments and switches on

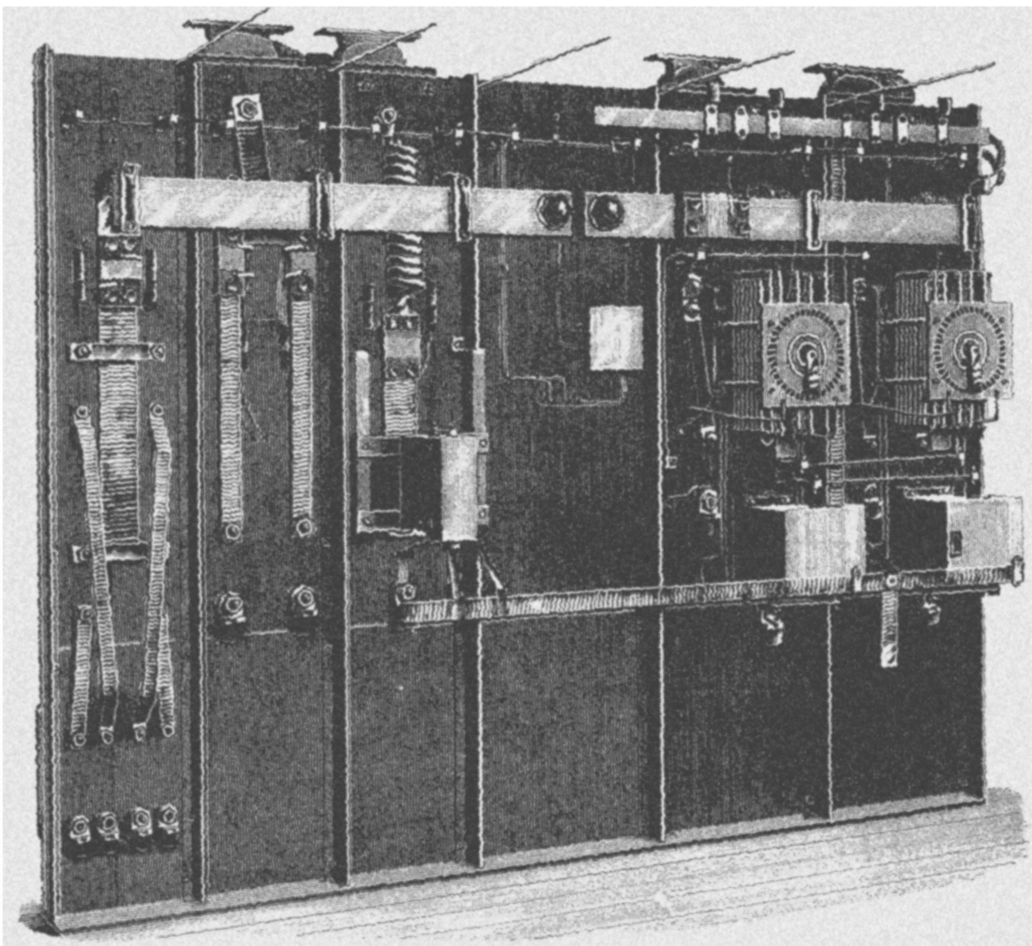


Fig. 282. Rear View of General Electric Company's Railway Switchboard.

both boards. Such an arrangement has been adopted for the switchboards of the Brooklyn City Railway Company.

Table LXXXIII. gives some details of the standard types of feeder witchboards constructed by the General Electric Company. These panels e supported by vertical angle-irons, and are adapted so that they can be 'ted side by side with the generator panels, making thus a continuous

switchboard. The connections between the generator and the feeder panels are made by extending the positive bus bar of the generator panel.

The three-wire system has been used with success in two American installations, Portland and St. Louis. In this system two generators are connected in series, the middle wire being attached to the rails, while the two other wires are connected to alternate insulated sections of the trolley line, as shown diagrammatically in Fig. 284. By means of this three-wire

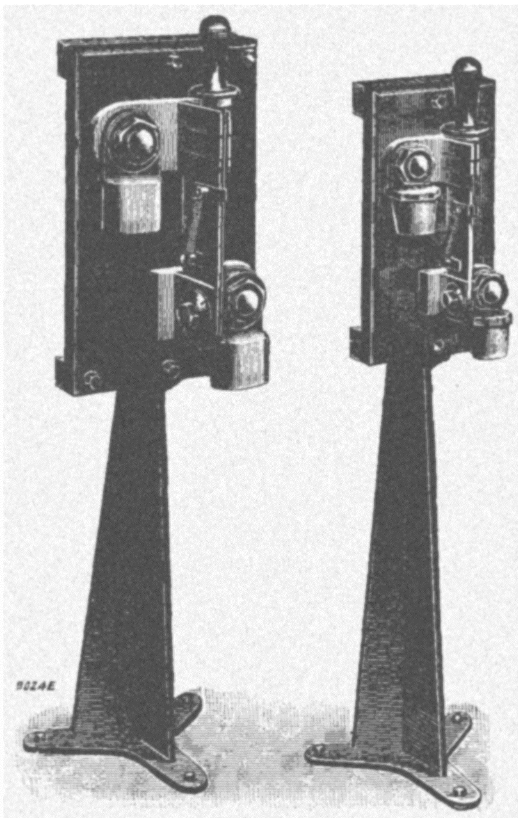


FIG. 283. EQUALISING SWITCH.

system, the current returning through the rails is notably reduced, as well as the section of the necessary feeders. The difficulty, however, in a railway system is to so arrange the sections as to maintain a fairly perfect balance between them. It would seem that the three-wire system is best adapted for double-track roads, or for lines having parallel lines, or lines located close together. In designing the switchboard to be used in connection with a three-wire system there is no necessity to make any alteration in the design of the instruments used. In the feeder panel the connections

should be arranged in such a way that the load can be maintained equal on both sides of the system by transferring the feeders from positive to negative, or *vice versâ*, by means of double-throw quick-breaking switches, whenever required by the fluctuation of the load. If at any time during a very light load, as, for instance, at night, it is desirable to run only one generator, all the feeders can be thrown on one side of the circuit, thus making the ordinary two-wire system.

In early electric railway plants, it was thought sufficient to connect the feeders to switches on the main switchboard. Owing to the very large number of feeders used on lines such as are now running in America, and to the very large units which have been found to be so much more economical than the smaller ones formerly used, it has been found advisable, as already stated, to have a special feeder board separate from the main switchboard. It often happens that through some temporary cause one of the feeders carries an extremely heavy current, which, if no switching

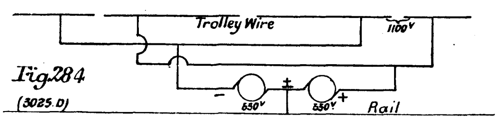


DIAGRAM OF THREE-WIRE SYSTEM.

arrangements were made, might burn up or disastrously injure the insulation of the cable. Furthermore, it is desirable to be able to know at each instant what amount of power is being consumed on the various sections of the line. The feeder panels are, therefore, furnished with magnetic circuit-breakers if the currents are heavy, and with fuses when they are light. Besides this, an ammeter is generally provided for each feeder circuit.

TABLE LXXXIII.—DATA REGARDING GENERAL ELECTRIC COMPANY'S STANDARD FEEDER PANELS.

Type.	Capacity of Circuit-Breaker.	Number Supplied.	Capacity of Ammeter.	Number Supplied.	Capacity of Switches.	Number Supplied.	Sectioned Area of Cable Connection.	Number Supplied.	Number of Fuses.
	amp.		amp.		amp.		circular mils.		
A	1,200	1	1,500	1	1,200	1	500,000	1	
B	1,200	1	1,500	1	600	2	500,000	2	
C	1,200	1	1,000	2	600	2	500,000	2	
E	...	...	...	...	400	4	300,000	4	4
F	...	...	1,500	1	400	4	300,000	4	4
G	...	...	600	4	400	4	300,000	4	4

As stated previously, when water power is used for driving the dynamos, the speed regulation of the turbines is very difficult. A very ingenious

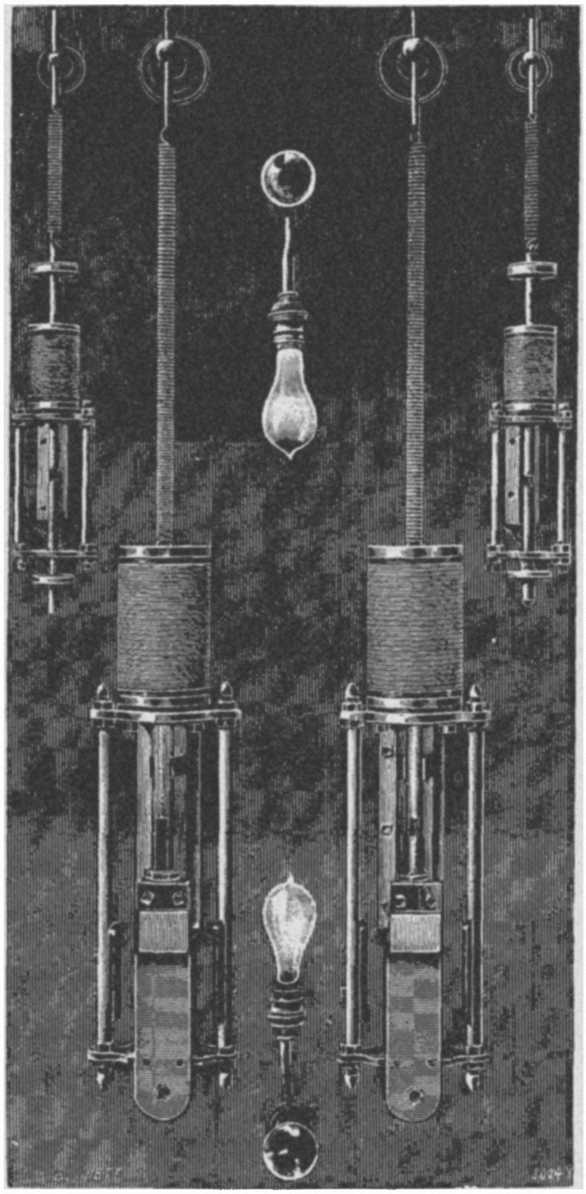


Fig. 285. Automatic Switches for Keeping Constant the Output of Turbine-Driven Railway Generators.

way of overcoming this difficulty has been adopted in the power station of the Niagara Falls Park and River Railway, which connects Queenstown, on Lake Ontario, with Niagara Falls. In this station, where the water

power is obtained free of cost, automatic switches have been arranged on the switchboard in such a way that the output of the generators is kept constant whatever the number of cars running may be. Fig. 285 gives an outside view of this apparatus, and Fig. 286 is a diagram showing its method of working. A represents the armature of the generator, S the series winding of the field, *s* the shunt winding, *e* is a high resistance electro-solenoid in which a plunger L works. This plunger is attached at its upper end to a coil spring. E is the low resistance solenoid; R is a carbon, iron sheet, or wire resistance which, in the present instance, is 7 ohms, and capable of having a current of from 50 to 60 amperes pass through it. If the car stops, and the current of the line decreases, the voltage of the generator has a tendency to rise. This causes the attracting

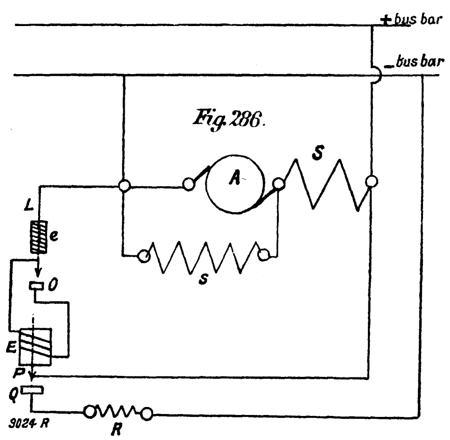
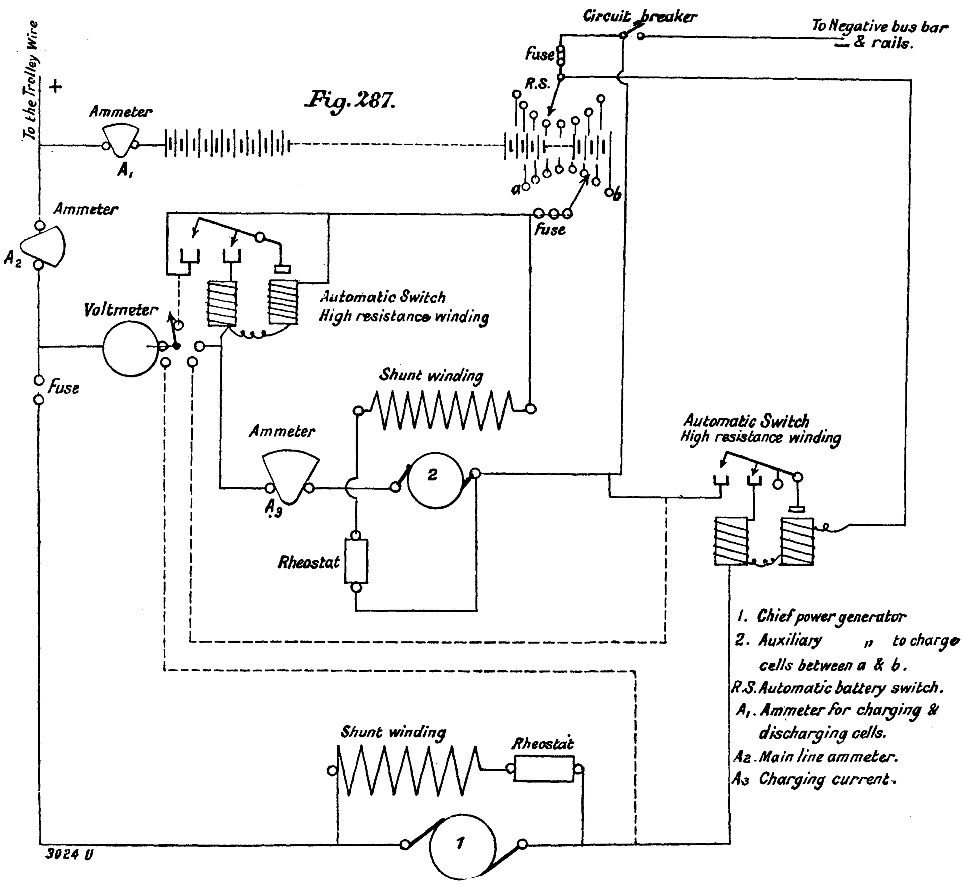


Diagram Showing Method of Operation of Switches Shown in Fig. 283.

power of the high resistance solenoid *e* to increase. L is sucked down, makes a contact with O, thus short-circuiting the low resistance solenoid E; the plunger P is let go, and makes contact with Q, thus bringing R into parallel on the main circuit. All the contacts are of carbon, and when this station was visited last summer the system was found to work excellently.

Up to the present time there are very few instances of the use of accumulators as a reserve in electric tramway installations, although in lighting practice this is very generally done. It is, therefore, of some interest to note what special connections have to be made on the switchboard when storage batteries are employed. A very interesting plant, erected by the Maschinenfabrik Oerlikon, has been running for some time

at Zurich. Fig. 287 shows the connections used on this switchboard. The generators used are shunt wound. A small auxiliary generator is used to keep the regulating cells charged, and they are constantly being switched in and out by the automatic switch R S; 270 cells of 7 plates each are put in series; the main generator is always in parallel with the batteries. If the tension of the battery becomes higher than that of the generator, an



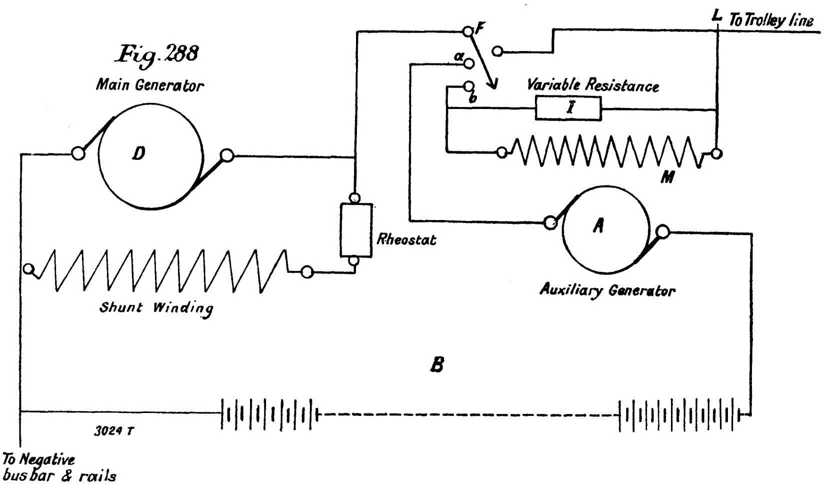
SWITCHBOARD CONNECTIONS OF ZURICH ELECTRIC RAILWAY PLANT.
(By the Maschinenfabrik Oerlikon.)

automatic switch cuts the generator out; when the reverse is the case, this automatic switch throws the generator on again. The last 81 cells of the battery near the pole are connected with an automatic regulating switch with 28 contacts, which switches cells in or out when the potential of the line falls or rises above a certain limit.

Fig. 288 shows another way of adapting a switchboard to the use of accumulators. This method is the one proposed by Mr. C. O. Mailloux, of

New York. The auxiliary battery is put in parallel on the terminals of the main generator D. The current to or from the battery passes through the armature A of a small auxiliary dynamo, the capacity of which is about one-tenth of that of the main generator. When the switch F is moved to the left, connecting *a* and *b*, the main current passes through the auxiliary generator. By this means an increase in the power absorbed by the trolley line augments the magnetism of this generator. The electromotive force added to that of the battery therefore depends on the load of the line. When little or no power is consumed on the line, the voltage of the battery B is below that of the dynamo D, and the battery will therefore be charged. When the load on the overhead line becomes very heavy, the voltage of the

Fig. 288



Switchboard Connections Proposed by Mr. C. O. Mailloux.

battery increases, and the battery gives out power on to the line. This system is just being installed for the first time on an American line.

Instruments usually Used in Switchboard Work.—The instruments which are necessary on a switchboard comprise circuit breakers, lightning arresters, quick breaking switches, ammeters, voltmeters, wattmeters, and rheostats. Of all these instruments the one which is, perhaps, of the most importance, and which is the most difficult to construct, is the circuit breaker. Of these there is probably none more efficient or better designed than that invented by Professor Elihu Thomson, and constructed by the General Electric Company. A great difficulty which has to be overcome in the construction of this instrument is the heavy sparking and burning out of contacts occasioned by the arc which is nearly always formed when

very heavy currents at high potentials are suddenly broken. This difficulty has been got over in the present case by the use of Professor Thomson's well-known magnetic blower arrangement. Fig. 289, from a photograph, represents the latest type as adapted for railway work. The main current passes through a heavy coil seen at the bottom of the instrument. When this current passes the limit to which it has been set, it pulls down the armature against the force of its supporting coil spring, and thus releases a catch which prevents the main contact-pieces from separating. A tendency to this effect exists, as a very heavy coil spring always tends to pull the

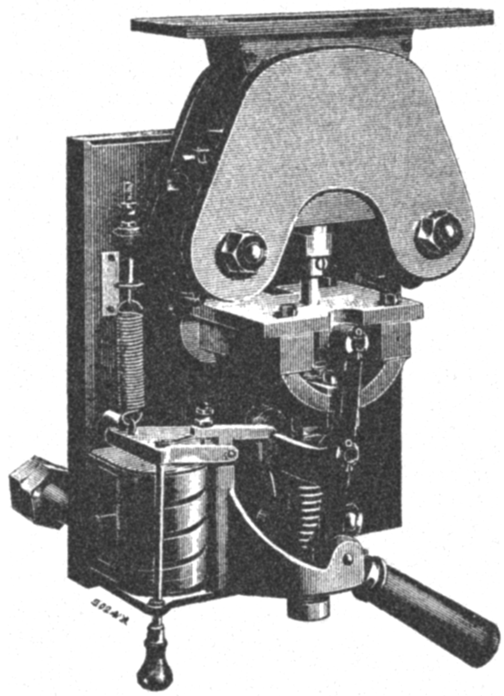


FIG. 289. THOMSON CIRCUIT BREAKER.

contacts apart. The current is not broken when the main contacts are separated, as besides these there are subsidiary contacts which are made between copper springs and carbon rods. It is here that the current is finally broken. These latter contacts are covered up by a fibre box shown at the top of the instrument, and inside which, by means of an electro-magnet, a very powerful magnetic cross field is generated. This field is so strong that the arc, which has a tendency to form between the carbon and copper contacts, is instantly blown out; in fact, in many instances it is prevented from forming.

Another instrument which is of the utmost importance is the lightning arrester. The "Ajax" type, which is largely used in the United States, has been already fully described.

Another type of station lightning arrester consists simply of a metallic tank into which there is a constant flow of water, and which is connected by means of very heavy connections to a good earth. Into this tank run a series of carbon rods, in many cases old lamp carbons being employed. These rods are connected to the feeder circuits. In Chicago it has been found advisable, owing to very heavy storms, to use three banks of lightning arresters at the power stations. Two of these are on the trolley side in each feeder circuit, and one is on the trolley side of each generator. One set is of the water-tank pattern above described. These are only put into circuit on the approach of a thunderstorm, as they waste a certain amount of current. At Chicago each of these arresters takes from 10 to 20 amperes.

Ammeters and voltmeters are too well known to need any particular mention. A word may, however, be said of the Weston instruments, which within the last few years have been extensively used in American railway switchboards. These are now being manufactured by Elliott, of London. These instruments are based on the principle involved in Deprez D'Arsonval's well-known reflecting galvanometer. They are very nearly dead beat, a quality of the greatest importance in work where currents vary very rapidly within wide limits. Another advantage of these instruments is that the scale is absolutely proportional throughout its entire range.

The switches generally employed in railway practice are of the knife-edge type and quick breaking. An illustration of the type of switch designed and used by the General Electric Company of America has already been given, Fig. 261, *ante*. It is composed of halves hinged together at one end, and connected at the other by a powerful coil spring. In opening this switch one-half is first pulled out, and the second is dragged out when the tension of the coil spring between it and the first half has become sufficiently great.

The "Ajax" is another switch extensively used in railway practice, and which has proved most satisfactory. This switch is composed of several copper knife-edges, which are held back by very heavy springs. The contact is not broken between the knife-edges, but between a special arrangement of copper springs and carbon rods, which can easily be replaced if at any time they should be burnt through. Fig. 290 shows an

"Ajax" switch lately constructed, and which is the largest quick-breaking switch ever made in America. It has a capacity of breaking a current of 7,000 amperes at 500 volts, an equivalent of about 4,600 electrical horse-power. The weight of this switch is over 400 lb.; it was constructed for the General Electric Company of America.

An instrument which should never be omitted from a railway switch-board is a recording wattmeter. By its use it becomes possible to know exactly how many electrical horse-power hours are consumed each day, and to keep a check on both drivers on the cars and the firemen in the boiler-house. Ampere-hour meters are of no use, as the potential on a railway station is always liable to vary between fairly wide limits. The best instrument designed for this purpose is, without doubt, Thomson's recording wattmeter, manufactured by the General Electric Company in America, and the Thomson-Houston Companies in Europe. This instrument has been so fully described in the technical press that it need not be gone into in this work.

FIG. 290. "AJAX" QUICK-BREAK SWITCH.

In cases where the currents dealt with are small, especially in feeder circuits, automatic circuit breakers are often replaced by fuses. Table LXXXIV. shows the capacity of fuses adopted for various units. These fuses are frequently made of copper wire, and Table LXXXV., for which the writer is indebted to the courtesy of the General Electric Company, shows the sizes of copper wire adopted in various cases.

TABLE LXXXIV.—CAPACITY OF FUSES USED IN RAILWAY POWER HOUSES.

Capacity of Generator in Kilowatts.	Capacity of Fuse in Amperes.	Voltage.
100	180	550 volts
200	360	550 ,,
300	550	550 ,,
500	1,000	550 ..

TABLE LXXXV.—SIZES OF COPPER WIRE USED FOR FUSES ON RAILWAY CIRCUITS.

"B. and S." Gauge.	Diameter in Inches.	Fusing Point in Amperes.
17	0.045	100
16	0.051	120
15	0.057	140
14	0.064	166
13	0.072	200
12	0.081	235
11	0.091	280
10	0.101	335
9	0.114	390
8	0.129	450
7	0.144	520

Table LXXXVI. shows the section of copper connections which are generally allowed for in the switchboard connections for various outputs.

TABLE LXXXVI.—SECTION OF CONDUCTORS USED TO CONNECT GENERATORS TO SWITCHBOARD.

Capacity in Kilowatts.	Circular Mills.
75	133,800
100	167,800
200	330,000
300	525,000
500	900,000

The instruments on the switchboard are frequently supported on enamelled slate or marble panels, angle-irons being bolted to each side to support them. The bottom of the angle-iron is fixed to the floor, preferably on a wooden beam, and the top is generally fastened by means of an insulated tie-rod to the wall. In some instances, instead of having the solid base, the instruments are fixed to wooden or insulated iron frames. Such switchboards are known by the name of "skeleton" boards. Ample space, 40 in. or more, should always be allowed behind the switchboard for making connections. In some instances, terra-cotta has been successfully used for switchboard work.

It is the usual practice to connect the generators in such a way to the switchboard, that the series coil of the field magnet winding is on the positive side of the armature.

It is of great importance that the connection between generator and switchboard, and between switchboard and overhead line, be made in such way as to be very accessible for testing purposes, and that individual wires

be easily recognisable. The best way to effect this object is to provide a trench running from generators to switchboard, and thence to the main feeder connected to the overhead line; this should be covered with an iron grating, easily removable, so as to give access to the wires running along the pit. This conduit should not be less than 3 ft. wide, its depth depending upon the number of wires which it will have to carry. Vertical timbers 3 in. by 3 in. should be put along the side of the pit, about 3 ft. apart, and securely fastened to the side of the wall.

The conduit from each machine should be connected to the main conduit, which runs to the switchboard. It should be so designed as to require the minimum length of conduit and wire, and to prevent the necessity of any cross wires.

The position of the wires should be decided upon before the wires are laid down, and the spool insulators inserted. The latter should be staggered when a number are to be placed side by side, and allow at least $1\frac{1}{2}$ in. between the surfaces of any two cables. Where any cables have to pass through a floor or wall, specially designed sleeve insulators, having rounded edges at either side, should be first inserted. These must be slipped over the cable before the ends are soldered into the terminals. Generally the best way to draw the wires into the conduits is as follows: The reels are set at the switchboards, the ends of the cables drawn through the conduit to the generator, and then drawn tight, strained towards the switchboard. Where a large amount of this work has to be done, it is found more convenient to pull up the wire at given intervals by means of blocks and ropes.

Where bus bars of switchboard panels are to be connected together, the best connection is obtained by first riveting the joints and then soldering and sweating them together.

The position of the switchboard has to be decided by the requirements of each case. It should be situated so as to be easily accessible from every part of the station, and from it a good view of both engines and generators should be obtainable. Moreover, it is desirable to so locate it that the length of the leads from the generators be as short as possible, and that there be as little difference as possible between the lengths of these connections. The direction in which the feeders must leave the station, and the location of the conduit, are very important elements to be considered.

CHAPTER XVIII.

CENTRAL STATIONS.

DYNAMO FOUNDATIONS.—The greatest care should be taken in providing good and firm foundations of brick, stone, or concrete for the generators. The depth and width at the bottom of the foundations will, of course, depend to a very large extent on the quality of the ground to be dealt with. In any case it is necessary to assure a foundation beneath the dynamo which will be stable without outside support, and the footing of the foundation must be securely bonded into the body of the work. In soft ground it is often advisable to build a common footing for both dynamos and engines, so as to insure their relative positions being maintained if slight settling takes place.

The following approximate rule may be of use in deciding the footings of foundations to be allowed under various conditions. In compact gravel the spread of the footings may be taken to be one and a half times the width of the foundation base. In stiff clay or sand the footing base should be twice the foundation base. Where stone or brickwork foundations are employed, and the base is soft clay, it is necessary to use concrete under the foundation proper. Great care should be taken in building up foundations to avoid continuous joints, and joints should, as far as possible, be perpendicular to the direction of the pressure they have to sustain. Dry and porous stone should be moistened before building in. Foundations made entirely of concrete are extremely good. A good mixture of concrete is made up of 1 part of Portland cement, 2 parts of sand, and 4 parts of broken stone, all by measure.

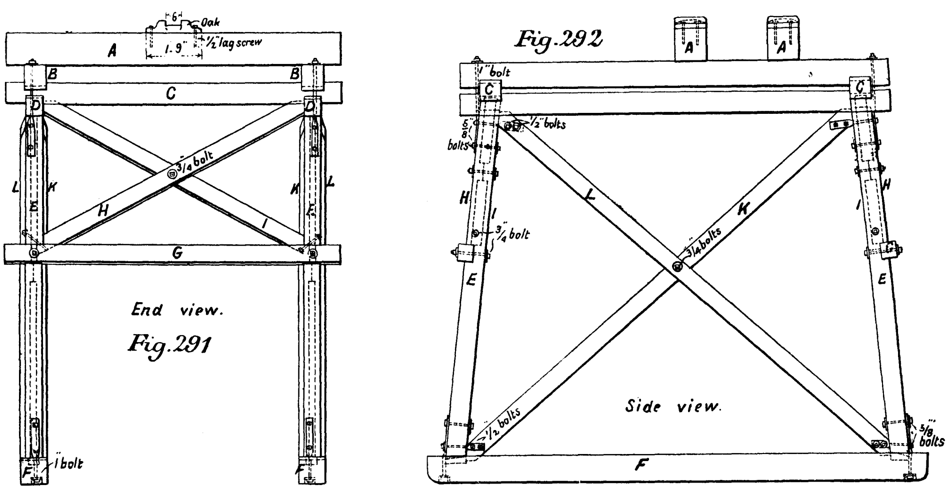
When bricks or concrete are used, it is often the practice to lay flat-faced stones about 6 in. thick, 24 in. wide by 81 in. long, in a good layer of cement on the top of the foundation, so as to bond the whole well together, and to evenly distribute the pressure of the rails when in place upon the foundations. The rails are blocked up by small wooden wedges about 1 in. above the stones. Great care must be taken that the rails are perfectly level, and that their slots are absolutely parallel with the centre

line of the belt. Ordinary stick sulphur is then melted over a slow fire, and is poured under the rails and between the foundation bolts and the foundation itself. Fibre washers are then placed under the nuts before the bolts are screwed down. By this means the foundation rails are entirely insulated from the foundation. The foundation bolts are generally from $\frac{3}{4}$ in. to 1 in. in diameter, and about 48 in. long. They usually reach to within 1 ft. of the bottom of the foundation, and extend sufficiently above it to allow of their being bolted through the lugs of the bedplates of the generators. They are held in place by iron plates or castings having a square hole through which the square heads of the fonndation bolts pass, which are thus prevented from turning round when the nuts are screwed up. The best way to determine the position of these bolts is to have a wooden template made of the generator base. This is adjusted above the pit where the foundation is built up in such a way as to be horizontal, and to occupy exactly the same position as the base will take later on. Square wooden boxes having the dimensions of the iron plate to which the holding-down bolts are attached, are then fixed vertically and centrally under the holes for the holding-down bolts which are marked off on the template. The foundations are then built up, and when completed the wooden boxes are taken out, the foundation bolts placed and adjusted in their proper positions, and the concrete filling put round them. In America it is a very general practice to attach the dynamo bases to wooden cross-beams bolted down by separate bolts into the foundations. In this case it of course becomes unnecessary to pour sulphur under the foundation rails. The holes into which the holding-down bolts of these timbers fit, should be countersunk so as to allow the top of the bolt to drop below the level of the bottom of the generator frame about $\frac{3}{4}$ in. Into these holes and above the bolts melted sulphur should be poured. To compensate for any irregularity in drilling the holes in the cap, these holes may be made larger with a downward taper, melted lead being poured in after the foundation bolt is in place and the position of the generator has been adjusted.

After the rails on which the generator base is fixed have been put in position, the base itself will be let down. It should be placed on the end towards the engine side of the centre, so as to allow the frame to be moved backward as the belt stretches.

In every engine-room a travelling crane should be provided, of such capacity as to be able to lift the heaviest part of either engine or generator.

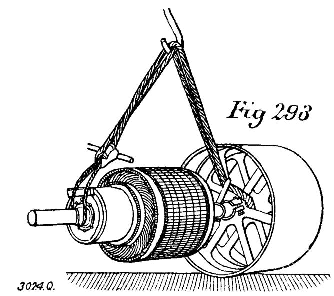
In a small station, manual power can be employed to move this crane, but in a large one, where it would be more or less constantly in use, it is advisable to work it by an electric motor. For use where a travelling crane is not available, the General Electric Company of America has got out an exceedingly simple wooden frame shown in Figs. 291 and 292. The following are the dimensions used for putting together one of their four-pole 500-kilowatt generators. The timbers are: A, 14 in. by 14 in. by 13 ft. 2 in.; B, 12 in. by 14 in. by 16 ft. 6 in.; C, 8 in. by 10 in. by 13 ft 2 in.; D, 8 in. by 10 in. by 11 ft. 6 in.; F, 12 in. by 14 in. by 18 ft. 8 in.; G, 6 in. by 8 in. by 13 ft. 2 in.; H, 6 in. by 6 in. by 11 ft.; I, 6 in. by 6 in. by 11 ft.; K, 6 in. by 8 in. by 18 ft. 6 in.; L, 6 in. by 8 in. by 18 ft. 6 in.;



Wooden Framework for erecting Generators.

M, 2 in. by 8 in. by 12 in.; *a*, 13 ft. 3 in.; *b*, 15 ft. 6 in.; *c*, 10 ft. 10 in.; *d*, 8 ft. 8 in.; *e*, 10 ft. The heavy timbers A to which the tackle is secured are not attached to the frame, but simply rest on it, so that they can be placed anywhere along it as may be most convenient. All joints are mortised and bolted, and the parts of the frame are so numbered that they can easily be put together after having been taken apart. The frame should be wide enough and high enough to stand astride of the assembled machine. The different parts of the machine can be lifted to the frame in their order of setting, and the whole can be rolled on hard wooden rollers over the floor of the station. The lower frame and extension base need not be taken to the trestle, as they can easily be lifted on to the foundation. If less than three generators are being assembled at one time, the use of such

a frame will hardly pay. A method adopted to lift the armature into place is shown in Fig. 293. A loop made of manilla rope $2\frac{1}{2}$ in. in diameter is passed in double through the spokes of the pulley, round the hub, and passed through the loop at the other end of the rope. A double rope is then passed over the lifting pulley, and the ropes crossed at this point. Two $\frac{5}{8}$-in. wire ropes, with loops in each end, are passed round the shaft outside the commutator, a small piece of wood being placed next the commutator to prevent injury. The looped wire rope ends are passed through the loop of the wire rope. A wire rope is used in this case because the room on the shaft between the bearings and the commutator is limited.



Sling for erecting Dynamo Armature.

On the wall opposite each generator, or, if this is too far, on a special panel close to the generator, a complete set of wrenches and tools should be fixed for every bolt and nut of the machine. This is of great importance, and saves much waste of time.

In some instances it has been found advisable to have special fans running on the same shaft as the armature, to ventilate it and keep it clean. Such an arrangement is working very successfully in the power house of the Chicago City Railway Company, where a special Westinghouse air pump pumps air at a pressure of 60 lb. to the square inch on to the commutator end of the armature. Wherever possible, it is advisable to have the dynamo on the same level as the engine, and not to belt up or down to it. It has been found in several instances in the United States that from this cause great trouble results from hot bearings, while the supervision necessary is much more difficult and costly. Plain flexible leather belts are preferred in America to any other belting. This may, perhaps, be accounted for by the excellent hides which the American manufacturers have at their disposal. Belts over 60 in. wide are of very frequent occurrence.

Running of Generators and their Care.—In running a dynamo great care must be taken to keep the commutator perfectly smooth. For this purpose fine sandpaper should occasionally be applied to the commutator while it is revolving slowly, at a point midway between the pole-pieces. Emery cloth should never be used, as particles get between

the bars, and cause short circuits, or else become fixed in the carbon brushes and cut the commutator. When new carbon brushes are put on, a piece of sandpaper should be fitted round the commutator rough side out, and the commutator slowly revolved. This will cause the brushes to take proper shape, and will prevent sparking.

Care should at all times be taken to keep all parts of a generator perfectly free from dust and oil, and to see that no dirt accumulates about the brush-holders. The carbon dust coming off the brushes should frequently be rubbed off. The commutator should be kept lubricated by occasionally applying to it a cloth slightly saturated with oil. Waste should on no account be used for this purpose, as it is apt to catch on the brushes, thus causing sparking.

It may sometimes happen that a generator fails to excite itself. If this is not due to bad contacts or to a breakage or wrong connections in the shunt winding, it may become necessary to charge the fields from another machine. When compound generators are in parallel it is necessary to connect them in three places, so as to prevent the possibility of one generator running the other as a motor. When machines of different sizes are connected in parallel, care should be taken that the resistance of the series winding and connections of all the generators be equal. Otherwise the machines will not divide the load in proportion to their capacity. In large machines it generally takes several hours for the shunt coil to get to its normal temperature. This means that the rheostat in this circuit will very frequently have to be altered so as to maintain the current to the shunt winding constant.

The following instructions must be observed when putting compound generators on an already live circuit:

1. The generator must be got up to its normal speed.

2. The rheostat in the shunt winding must be adjusted so as to give the same voltage between the terminals and the generator as that of the line.

3. Throw in the positive and negative generator main switches, and equalising switch.

4. The ammeter of the generator must be watched, and the field rheostat adjusted so as to make it take its proper share of the load.

If a generator should be thrown in parallel with another before its voltage is up to the same point, it will not do its proper work, and it may even be run as a motor with a current from another machine. If this

should happen, resistance should be thrown out of this machine. If the generators are run by means of belts, and one of the belts should break, the generator will continue running as a motor by the current off the line. To shut down a generator running in parallel it is necessary—

1. To throw resistance in with the rheostat so as to cut down its load.
2. To open the circuit-breaker and the three main switches.
3. To slow down and stop the engine.

In any case the greatest care should be taken that the shunt circuit of the generator be not broken while it is running. If this should happen, it is more than probable that the armature and series winding of one or more machines will be burnt out, unless these are instantly cut off by their fuses melting. When it becomes necessary to raise or lower the voltage of the line, the voltage of each generator has to be regulated. If the bearings should heat, the following alternatives should be tried before the generator is shut down. The load should be lightened, the belt slackened, the caps on the boxes slightly loosened, and more oil put into the bearings. If these remedies fail, a heavy lubricant such as vaseline or cylinder oil should be used. If all the above remedies are useless, it becomes necessary to shut down. The belt should be got off as quickly as possible, the machine meanwhile being kept revolving, so as to prevent sticking. The caps should be screwed off the bearings, and the flow of oil kept up. When the caps have been taken off, the machine should be stopped, and the linings of the bearings taken out and allowed to cool in the open air. When a machine is shut down, care should be taken that the brushes are all off the commutator, and that all switches and circuit-breakers are open.

In the early types of railway generators sparking at the brushes was very frequent, owing to the rapidly varying loads. With the very strong magnetic fields now used, this is no longer so, and heavy sparking at the commutators indicates that something has gone wrong somewhere. The fault is generally found either in the commutator or armature. A flat on the commutator is a frequent cause of sparking. Flat spots are usually caused by a warm commutator and by too much end play, or else by a loose commutator, or connection, or a bad belt splice. A heavy short circuit on the line is often the beginning of a flat which is started by the very heavy sparking at the commutator. If flats exist on a commutator, it should be turned down at once. This can be done without removing the armature, by using a special tool-holder fixed to the generator and revolving the armature. Sparking may also be caused by the brushes not being set

exactly to the diameter of the commutator, by their having been welded to their holders, by not being pressed firmly enough to the commutator, or by having their ends burned off. A heavy overload, a short circuit, or a dirty or worn-out commutator, are also causes of sparking. A loose or broken connection of the armature winding will cause a sharp blue spark whenever this bar passes under a brush. An open circuit in the armature will cause a bright flash, appearing to run completely round the commutator. A short-circuited coil in the armature also produces sparking. This can easily be detected, as a short-circuited coil rapidly heats and burns out. Short circuits are sometimes caused by copper and carbon dust getting between the segments of the commutator or brush-holder connections. Perhaps the most difficult fault to discover is a short circuit in the armature, which only takes place when the armature is revolving, and which is generally due to two consecutive armature windings being forced together by centrifugal force or magnetic drag, just at a point where a fault in the insulation exists. The heating of the magnet coils is generally due to a short circuit. It is, however, a very unusual occurrence in well-constructed machines.

It sometimes happens that a line is very heavily overloaded, either by a number of cars starting together or by an unusually heavy traffic. In this case circuit-breakers are constantly going off. The best remedy for this is to run up the voltage, when the trouble generally ceases. The cause is that the very heavy demand for power runs down the voltage and runs up the current, and the circuit-breakers therefore go. By raising the voltage the current demand is met, and the circuit-breakers will remain in place.

In starting up the generators of a new power plant for the first time, great care should be taken not to put load on them too suddenly, so that any small defect existing can be remedied before serious results follow. When first started it is advisable to run the generator slowly with lightly excited field on to some external resistance—say a series of lamps—for several hours. Where generators have been lying about for some time before being put up, their armatures should be dried in a regular drying oven if possible, as moisture is sure to collect in the armature, and if not thoroughly dried out the dampness may cause a short circuit and burn out the armature. A current should also be passed through the field magnet, but with a much lower voltage than will actually be employed when the machines are running. Another mode of getting rid of the moisture is to put all the resistance of the field rheostat in series with a shunt winding, and to slowly run the

machine on an open circuit so as to attain from a third to half the normal voltage at the terminals. If this is done for some hours, the current which goes through the armature and shunt winding, as well as the heating of the armature core due to hysteresis, will dry out the machine. Where current from other sources is available, the armatures can be fixed so as to prevent them rotating, a heavy resistance put in series with them, and a small current run into them, as well as through the field windings.

The following is the sequence to be followed in putting generators in parallel when the switching arrangement of the General Electric Company, which has already been described, is used. The equalising switch is first closed, after which the positive switch is thrown in. This throws the series winding of the field into parallel with the generators already running. The field switch is then closed, thus putting the shunt winding of the field in parallel on the circuit. The generator is then run up to full speed, and when the voltage at its terminals is equal to the voltage of the line, the negative switch is closed. The way very generally adopted for cutting a machine out of circuit by switchboard attendants, is by breaking contact at the circuit-breaker.

The number of men required to run a station is very variable. For a 50 to 100 car road, with one power-house, and having all modern improvements, the following list is approximately correct:

Chief engineer and electrician.	Two dynamo tenders.
Assistant engineer and electrician.	Two oilers.
One chief engine-driver.	One cleaner.
One assistant engine-driver.	Four firemen.

One coal-passer.

Forced Draught.—Although forced draught has been applied with success in connection with marine engines, it has rarely, as far as we are aware, been used in connection with ordinary stationary engines on this side of the Atlantic.

As has already been seen, the load in electric traction power stations is exceedingly variable, and it often happens that, owing to some unusual or unforeseen circumstance, a large number of additional cars have to be run out upon a very short notice. To insure a good natural draught, it is necessary for the chimney to be of sufficient height. Where economisers are used, a far stronger draught has to be provided than would otherwise be the case, which means constructing a much higher stack than would otherwise be necessary. To avoid this, as well as the attendant expense of

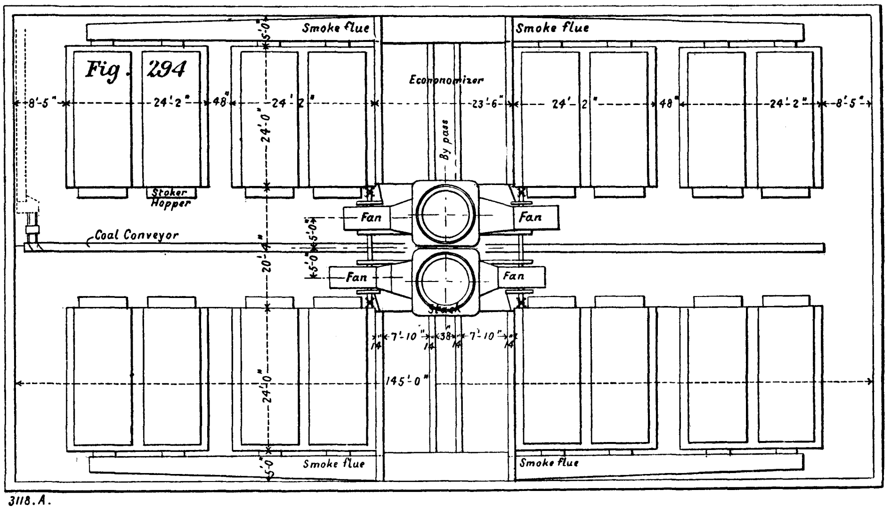
heavy foundations, mechanical draught has to a certain extent been adopted in America. It possesses an advantage over natural draught in that it is flexible, and easily meets sudden and excessive demands for steam. Table LXXXVII., compiled from tests by Mr. William Roney, may be interesting as showing the saving of fuel which is claimed for this mechanical system of artificial draught. Figs. 294 and 295 are a cross-section and a plan of one of the largest applications of this system in the United States, that of the Philadelphia Traction Company at its station in Thirteenth-street, Philadelphia. This plant was erected by Westinghouse, Church, Kerr, and Co. The waste gases, after leaving the boiler, are utilised to heat the water in a Green's economiser. On each side of the smoke-stack is situated a large Sturtevant fan, which forces the gases up the chimney. There are at present in this station four compound engines of 600 rated horse-power each. Room is provided for 14 more. The engines are of Westinghouse type, and are directly connected with four-pole Westinghouse generators, having a capacity of 460 amperes at 500 volts. The amount of power which such large regulating fans absorb is not so great as might be imagined. The fans in the above-named station use less than $\frac{1}{2}$ per cent.

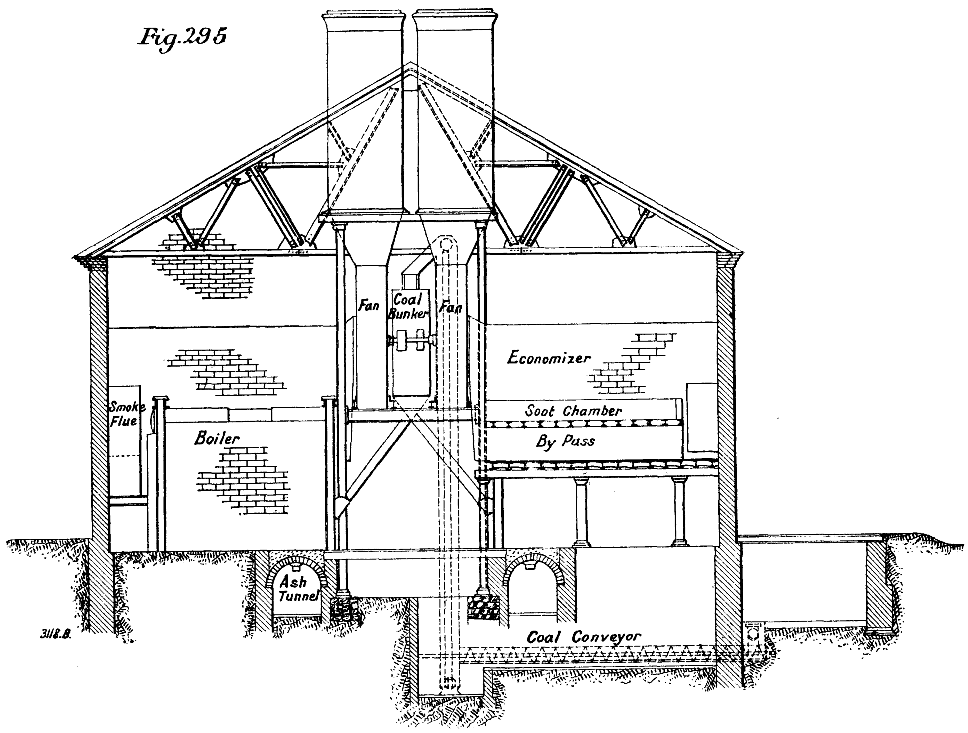
TABLE LXXXVII.—Tests of Economiser and Mechanical Draught Plants, Showing Initial and Final Temperatures of Flue Gases and Feed Water in Degrees Fahrenheit.

Plants Tested.	Gases entering Economiser.	Gases leaving Economiser.	Water entering Economiser.	Water leaving Economiser.	Gain in Temperature of Water.	Fuel Saving per Cent.
1	610	340	110	287	167	16.7
2	505	212	84	276	192	19.2
3	550	205	185	305	120	12.0
4	522	320	155	300	145	14.5
5	505	320	190	300	110	11.0
6	465	250	180	295	115	11.5
7	490	290	175	280	105	10.5
8	495	190	155	320	165	16.5
9	541	255	150	311	181	18.1

Mechanical Coal Handling.—Where the cost of labour is extremely high, very expensive and intricate machinery is often employed to reduce the number of workmen. In large power-houses, where there is a heavy daily consumption of coal, the handling becomes a very expensive item. It is not always possible to so locate a power-house that the coal can be directly discharged from the hold of a ship into the bunkers, or so that cars

can be directly run in. To decrease as much as possible the cost of coal handling, the C. W. Hunt Company, of New York, has designed an elevator





SECTION AND PLAN OF MECHANICAL DRAUGHT PLANT AT PHILADELPHIA.

and conveyor which has been very largely and successfully employed. The scoops or shovels used to lift the coal open out 7 ft., and carry from 1 to

$1\frac{1}{2}$ tons. They not only save labour, but also prevent breakage. Such a shovel and elevator are shown in Fig. 296. The operation of this shovel is very simple. A single hoisting engine is employed, and when the shovel reaches the top of the booms over the hopper it is automatically tipped. The engine-driver has nothing to do but to hoist up to the mark, and then lower into the hold of the vessel, with the scoops open and ready for filling.

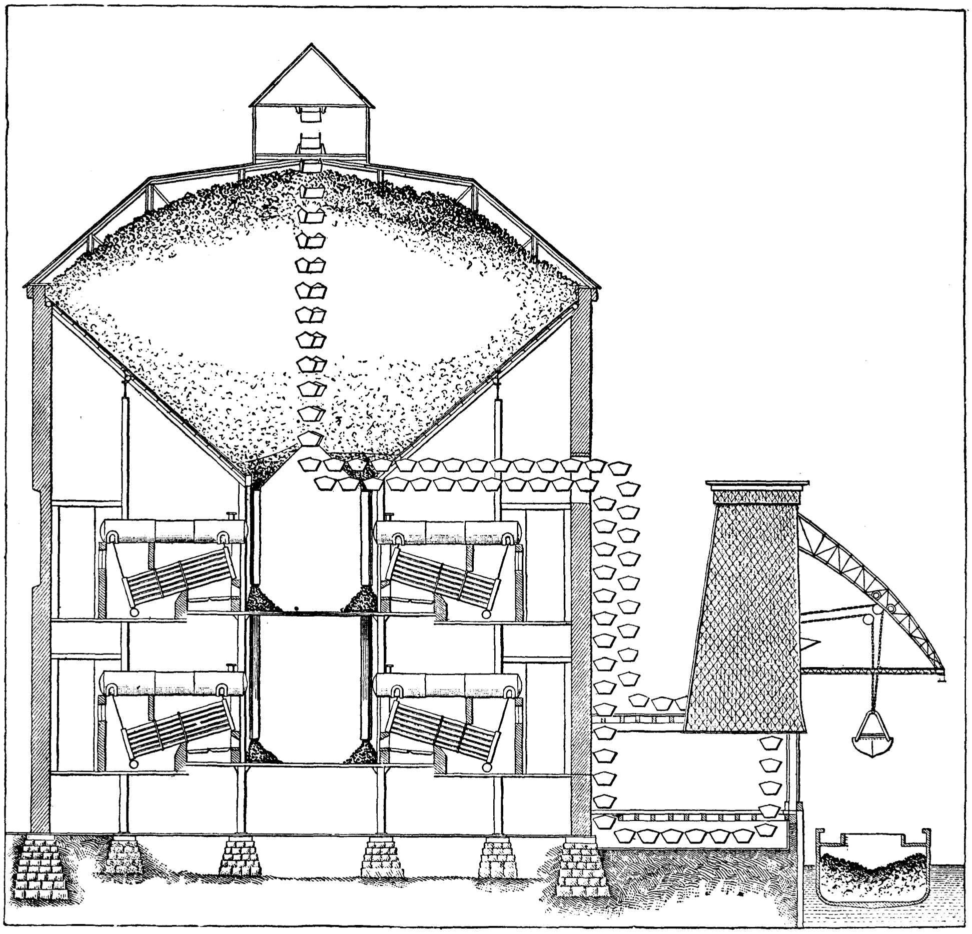


FIG. 296. COAL-HANDLING PLANT.

The saving of expense in unloading vessels is very great. It has been found in New York that the average expense for lifting by this means does not exceed $1\frac{1}{2}$d. per ton of coal. The wear and tear of machinery is slight, and the repairs to the shovel are not heavy, and it is stated will not exceed the twentieth of a penny per ton of coal hoisted. This steam shovel makes about one trip per minute, so that its capacity of unloading varies between

N N

60 and 80 tons per hour, and in favourable instances it has reached 100 tons. The conveyor, which is used for carrying the coal from one place to another after it has once been lifted, consists of a series of buckets suspended in such a way that they are upright, no matter what position the chain which connects them may occupy. The chain which connects the buckets is composed of heavy wrought-iron links. The axle which connects one link to the other is provided with small flanged wheels, which run on rails provided for the purpose. This axle is thoroughly lubricated, and the links of the chain are long, so that but few joints are necessary. As the buckets swing freely on pivots, some special method for loading them is required. Two methods of doing this are adopted by the Hunt Company, one known as the "measuring" filler and the other as the "spout" filler. The first, as its name implies, is arranged so as to deliver to each bucket a given quantity, and it is suitable for material up to a certain size. The "spout" filler is a continuous feed, each bucket filling as it passes underneath it. This conveyor is not driven by an endless chain, but by a set of pawls which push the endless chain along. It is claimed that that method gives a smoother motion, and also permits the power to be applied to such parts of the chain as may be most convenient. The chain is run at a very low speed, and sufficient capacity is obtained by having large buckets. The ordinary size of chain, with buckets having a capacity of 2 cubic feet each, runs at a speed of about 15 buckets per minute, or above 40 tons of coal per hour. Should a greater capacity be necessary for a short time, the speed can be increased to 25 buckets per minute, or about 80 tons of coal per hour. This conveyor has also been used very successfully for conveying away the ashes and clinkers from the stokehole. Fig. 296 shows the cross-section of the Brooklyn Heights Railroad Company's boiler-house and coal storage.

The line of the boilers is parallel to that of the wharves, as shown. The coal is received in vessels, and in case of the failure of this source of supply, means are provided to obtain it in wagons from the local coal-dealers. The building having been erected before the installation of the machinery, it was necessary to adapt the machinery to existing conditions. The conveyor could not be carried vertically downward at the end of the storage bin on account of lack of space. These conditions required that, besides being lifted over 100 ft. vertically, the coal had to be carried horizontally in two directions, at right angles to each other. The upper line of the conveyor chain over the storage pocket runs at right angles to

the lower, and the change of direction is accomplished as shown in Fig. 297. The coal shown ascending in the line of conveyor on the right,

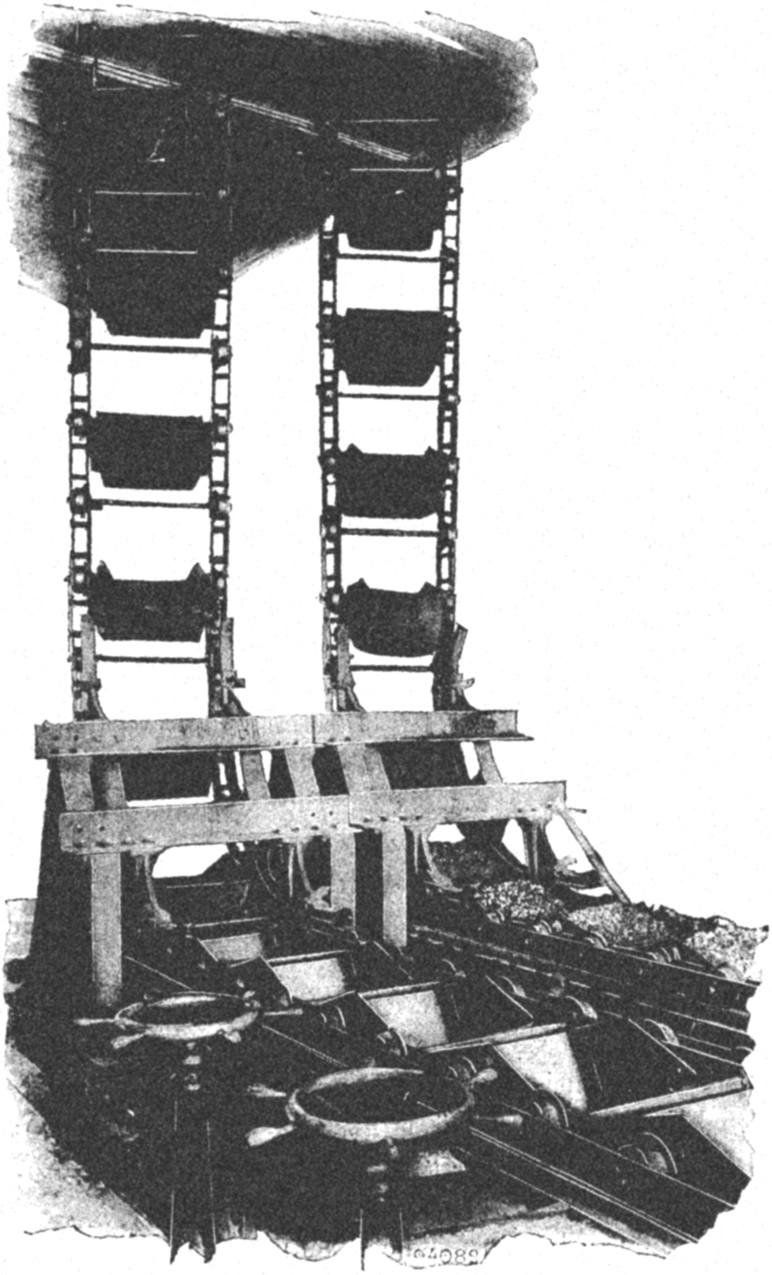


FIG. 297. CONVEYOR CHAIN; COAL-HANDLING PLANT.

is dumped in the storage pockets. The empty buckets are shown returning on the left. The conveyor moves horizontally and then vertically. While

moving vertically, the buckets take the position shown in the cross-section of the boiler-house, and turn through a right angle, so that when the conveyor again moves horizontally, the direction of motion has been turned through 90 deg. The unloading from the vessel is accomplished by means of an elevator and steam shovel, fitted with a double cylinder rapid hoisting engine.

The elevator booms which are shown over the hatch of the vessel, Fig. 296, are pivoted on a vertical axis, so that they can be swung horizontally over the wharf, leaving the dock front unobstructed when not in use. The steam shovel descends upon the coal with the scoops wide open, and when the hoisting engine is started the scoops close, pushing themselves underneath the coals, thus filling the shovel. The storage pocket above the boilers holds easily 6,000 tons, and is so arranged that all of the coal will run to weighing hoppers, from which it is spouted to the floors at a convenient shovelling distance from the furnaces.

Fig. 298 gives a longitudinal section of the system of coal-conveying now in operation at the Southern Power Station of the Brooklyn Heights Railroad Company. The 12,000 horse-power for operating the electric street railways in the southern part of Brooklyn is supplied from this station. As stated above, the conveyor had to be placed in a building already erected, and in such a position as the steam pipes and the opening in the roof trusses permitted. A water-tank situated at the end of the boiler-house made it necessary to place the coal storage pocket, holding 8,000 tons, 90 ft. away, and to carry the coal to the boilers by a conveyor over a single-span steel truss bridge 46 ft. above the tank in order that this space should be unobstructed. The coal is received from the vessels lying at the side of the pier, 800 ft. distant.

It will be seen that to handle coal at the lowest cost per ton in this station, required in this case an elaborate and expensive installation. As completed, the plant consists of:

1. A coal-hoisting plant of large capacity, to unload rapidly and economically every type of coal-carrying vessels coming to New York Harbour.

2. A cable railway to carry the coal 800 ft., and deliver it at any point in the coal pocket at a height of 37 ft. above the wharf.

3. A conveyor taking coal from any part of the storage pocket, and delivering to the furnaces as required from hour to hour.

The hoisting machinery used on this dock is the usual steam shovel

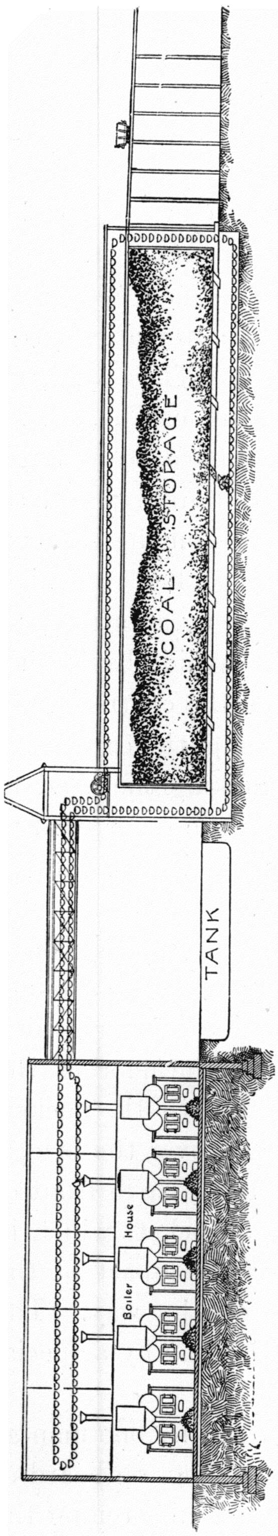


Fig. 298. Section Boiler House and Coal Store, Brooklyn.

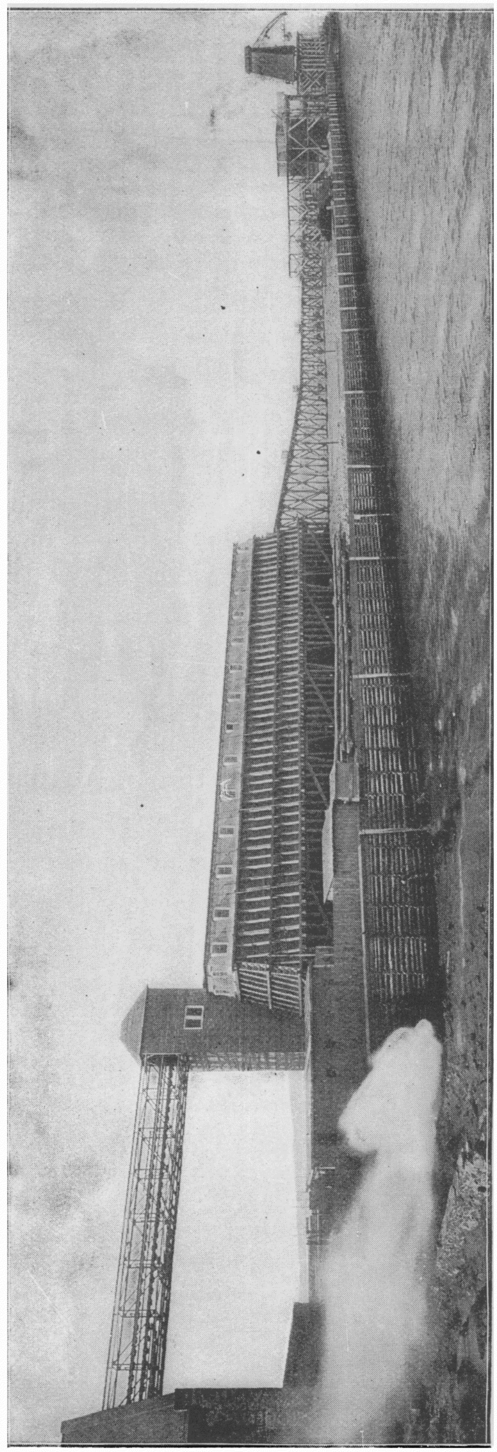


Fig. 299. Coal-Handling Plant, Brooklyn Heights Eastern Power Station.

and elevator, similar to that on the wharf of the Eastern station of the same company, using a double-cylinder hoisting engine taking steam from the main boilers 800 ft. distant (see Fig. 299). The elevator is movable on the trestle, and can be placed opposite to any hatch of the vessel from which it is desirable to unload the coal.

The cable railway which carries the coal from the elevator to the storage pockets is $21\frac{1}{2}$-in. gauge, and built on a trestle about 18 ft. high. The cars hold $2\frac{1}{2}$ tons. The bottoms of these cars are inclined each way from the centre to the sides, and the coal is discharged automatically on both sides of the track at any point in the coal pocket. These cars are drawn by a steel cable driven by a double-cylinder steam engine. The speed of working is low, the required capacity being obtained by a large number of cars, which are dumped automatically at any desired point, so that it is not necessary for an attendant to accompany them on the trips up the track to the pocket and around the curve shown in Fig. 300, returning to the outer end of the wharf, where the grips are released by an attendant and the car loaded at the elevator for the next trip. To avoid obstructing the wharf, the track is placed back from the front and in the centre of the pier. When passing around the curved track in the building, the cable runs on a large number of self-lubricating carrying wheels, making the bend in the easiest manner, and thus increasing its durability. The grips used to attach the cars to the cable are designed in such a way that in passing around a curve the rope is not subjected to a sharp bend.

The storage pocket holds 8,000 tons of coal, and stands entirely on a pile foundation. The bottom of the pocket is elevated above the ground, and inclined in such a manner that the coal will run to the conveyor, which is placed in a passage in the centre of the space under the floor of the building. The lower line of the conveyor passes underneath the pocket, where the buckets are loaded with coal, thence it passes up over the bridge into the boiler-room, from which the coal is spouted to the floor in front of the boilers. The conveyor on its return passes over the pocket, which in case of heating would permit of the coal being taken from one part of the pocket to another, the exposure to the air cooling it on the way. The loading of the conveyor buckets underneath the pocket is done by a special filler.

The work of handling coal at this station is performed by one man at the engine in the tower, hoisting coal from the vessel, one man on board of the vessel, one man loading the cable railway cars, one man unfastening the

grips on the cable, and in charge of the cable-driving engine, and of such work as may be needed around the wharf. The speed of unloading coal is varied to suit the vessels and the work. The bucket at its usual speed makes one trip per minute, and carries about a ton at each trip, hoisting about 60 tons per hour. The average day's work is less than that, as there are delays in shifting from one hatch to another, and in cleaning up boats, which reduces the average work.

Boilers.—The question as to what type of boiler is the most suitable to employ in connection with electric traction is a very disputed one, and

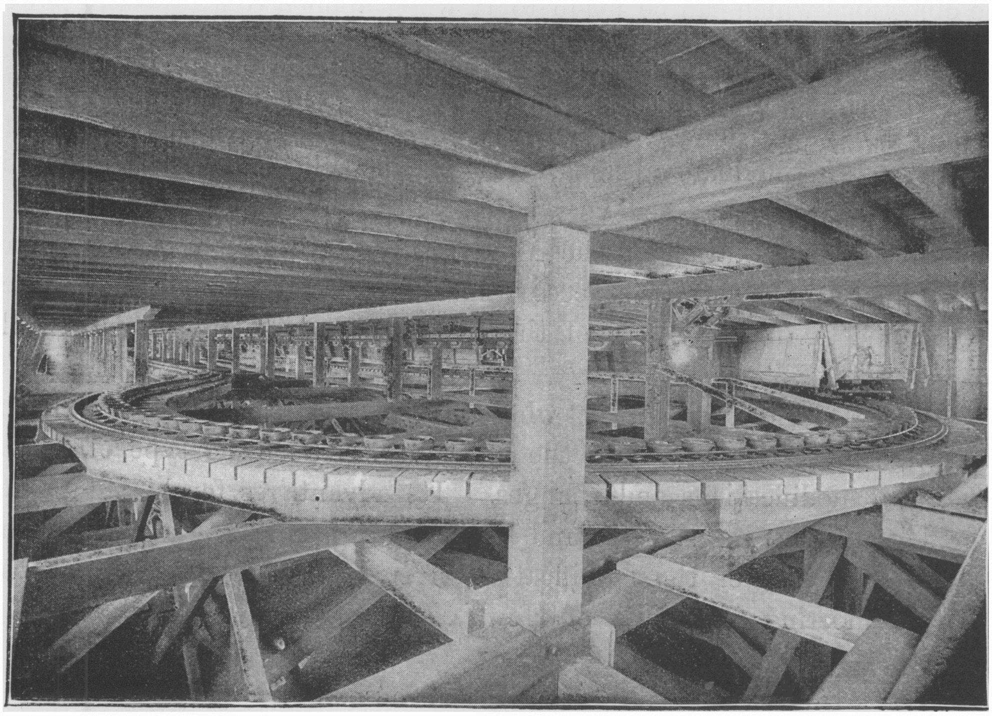


Fig. 300. Coal-Dumping Plant; Curve at End of Track.

different engineers hold very different opinions on this subject. It is certain, however, that no decision can be come to on this point without a clear knowledge of the conditions which have to be fulfilled in each case. Some points, however, which are specially called for are simplicity of construction, supply of dry steam, rapidity of getting under steam, and possibility of overworking for a short period. The tendency of the present day seems to be to use high pressures, and there is little reason to doubt that still higher will be used in the near future. A very large number of different types of boilers are used in the United States, some of which are

little known or cared for on this side of the water. There are many stations in America where colossal vertical boilers are used. The types of boilers mostly used may be roughly divided up as follows:

Horizontal boilers of the Lancashire type.

Marine type of boilers.

So-called safety water-tube boilers, and

Vertical boilers.

It would seem to be undisputed that from the economical point or view for steady loads, no boiler surpasses the horizontal Lancashire type. The objections which can be made to it when applied to a tramway power plant are that it takes a long time to get up steam, and that it is very difficult, if not impossible, to force these boilers at short notice when sudden calls for power are made. It is probable, however, that in very large stations where the load, although varying, remains fairly constant, this type of boiler could be used very successfully. As an example of such a station, the power station of the Montreal Street Railway may be cited. Where land is expensive or access difficult, the large amount of space required and the heavy weight of the parts of these boilers are undeniable drawbacks.

Some American engineers, where loads are subject to very violent fluctuation, are inclined to use the internally-fired marine type of boiler, with a few modifications and changes. Its advantages for high pressure and efficiency have been proved and developed in marine engineering. The following abstracts of the specification of such a boiler installed by the Field Engineering Company, of New York, for tramway work, may be instanced.

TYPE.—Internally-fired direct tube marine boiler.

PRESSURE.—Working pressure 160 lb., water pressure test 210 lb.

CAPACITY.—To evaporate 3 lb. of water from 100 deg. Fahr., and 70 lb. pressure per square foot of heating surface per horse-power.

ECONOMY.—To evaporate 9 lb. of water from 120 deg. Fahr. at a temperature corresponding to 160 lb. steam pressure per pound of good anthracite pea coal when developing its rated capacity.

QUALITY OF STEAM.—The steam furnished by the boiler at its rated capacity not to exceed 2½ per cent. of moisture.

FURNACES.—Corrugated or Adamson's type, with common combustion chamber.

RIVETING.—Longitudinal seams of shell to be butt-jointed and double-

butt strapped, and triple-riveted each side of butt. Circumferential seams to be double-riveted. Flanges and heads to be single-riveted. All holes to be drilled when sheets are in position for riveting.

STAYING.—Boiler to be stayed to withstand 150 lb. working pressure. Strains on welded braces not to exceed 6,000 lb. per square inch. Solid stays; strains not to exceed 900 lb. per square inch section. All stays, braces and rivets to be of the best double refined iron.

MANHOLES AND HANDHOLES.—Each boiler to have at least four manholes and a sufficient number of handholes.

PLATES.—All plates to be of best steel, 60,000 lb. tensile strength.

FRONTS.—Boiler to be equipped with neatly designed furnace fronts and cast-iron bridge walls.

The special advantage claimed for this boiler is that it has an enormous capacity and can furnish almost any amount of steam when forced, and that the steam is of good quality as regards the percentage of moisture.

As regards the water-tube boiler, of which so many types exist, little need be said here, as it is already so well known in connection with lighting and power plants.

A very favourite form of boiler in the United States, owing probably to the small space it occupies, is the vertical type of boiler, often reaching 30 ft. to 40 ft. in height. There are any number of boilers of this type, slightly varying in construction. Some of these will be touched upon in future chapters, describing typical traction power-plants.

The care of boilers is always an important point, and should only be entrusted to competent men. Great care must be exercised to see that the proper water level is maintained, and that there is no sudden drop of the steam pressure, which, owing to the very large and often unexpected variation in load, is always likely to occur.

The piping of the power-plant is exceedingly important, as upon it depends the safety, economy, and reliability of the station. Some engineers think it necessary to put in a duplicate system of water and steam piping throughout, which often leads to very serious complication in erection. This duplicate system of piping, although theoretically advantageous, is not necessary, if the best material and the greatest care in erection, fitting, and manufacture, are employed. In most cases a complete loop would seem to be the most economical and reliable mode of setting up steam pipes. When possible, high pressure steam piping should be supported from underneath, and not swung. This method eliminates that vibration so often noticed,

and which results in leaky joints caused by racking and straining. The whole system of piping should be blown out thoroughly with steam before the engine connections are made, so as to prevent chips or dirt being carried through into the cylinders.

Great care should be taken to have all boilers and steam pipes coated with a good anticaloric substance, so as to reduce condensation in the pipes to a minimum. It is, of course, evident that in designing a power-house, all care should be taken to reduce the length of the steam piping as greatly as possible. Amongst the numerous auxiliary appliances, used successfully in America, may be mentioned the automatic damper regulators which maintain constant steam pressure under nearly all conditions. Some of these regulators are so good that steam pressure is kept constant to within $\frac{1}{2}$ lb.

Car-Sheds and Repair Shops.—The car-house of an electric railway plant differs in many ways from that used with other modes of traction. The shed should be so arranged that easy access can be obtained to every individual car, both from the sides and from below. It is usual either to have pits extending nearly the whole length of the tracks inside the car-shed, or else to support the rails on longitudinal sleepers, which in their turn rest on brick or wooden piers, the space between adjoining tracks being floored over. The latter system is, perhaps, the more advisable, as a foreman can easily see what is going on underneath all the cars, and the men can easily circulate from one car to another. In small car-sheds, however, where the cars are cleaned and washed down over the pits, this system is not to be recommended, and separate pits are better. The car-pits should under any circumstances be able to accommodate at least 25 per cent. of the cars.

The car-shed should be well lit from above, and, if possible, from the sides as well; the side lights, however, being placed sufficiently high to light the tops of the cars. There must be efficient lighting at night, especially in the pits. Well-protected armoured plugs should be set every 12 ft. or so along the pits, with flexible connections to 16 or 32 candle-power lamps protected from injury. Where the pits are utilised for washing cars, water plugs at short intervals should also be set in the car-pits.

Every car-shed should be provided with at least one traverser. There are two types of these, the one having wheels which run on rails at the same level as the tracks, the cars being moved on and off the

traverser by an incline. In the other type the traverser rails are sunk so that the cars can run straight on or off the traverser without any incline. The advantage of the latter system is that labour is saved. On the other hand, there is a certain amount of space lost, as the whole space over which the traverser travels is unavailable for storing cars. In large car-sheds, where large numbers of cars have to be removed from one line to another, and from the car-shed into the repair shop, traversers should be moved by mechanical power. This can be done either by having a motor at one end of the traverser truck and an endless rope, or else by having a motor mounted on the traverser and working it directly.

Repair Shops.—The repair shop is an important part of an electric tramway system, and its importance increases with the size of the plant. In moderate stations it is sometimes questionable as to what repairs a tramway company should execute on the spot, and what ought to be sent out to be done. This depends to a great extent on location. A line situated in the centre of a manufacturing district would probably find it cheaper to have large machine work or castings done outside, whereas a line which is obliged to send some distance to have its repairs made would probably find it cheaper in the end to do most of its work itself. The question of how large the repair shop and staff should be, and what tools should be installed, must be decided for each individual case. It is certain, however, that roads running several hundred cars should in all cases make their own repairs.

The repair shop must be situated as near the car-shed as possible, and preferably under the same roof. In large shops it will always be found convenient to work the heavier tools by separate electric motors. The ordinary small tools which are constantly in use should be driven in groups from countershafts driven by separate motors. This is the practice which is adopted by a very large number of manufacturers who are introducing electricity in their works. By this method it is possible to subdivide units and to do away with a large amount of wasted power absorbed by long countershafting and belting. The amount of work which a repair shop must do depends on the quality of the equipment, and upon the way in which it is treated. Careful management and constant supervision will very much diminish repair bills.

In order to settle what repairs must be provided for in the repair shop, we will examine what constitutes the legitimate repairs of a road which desires to keep its equipment up to an economical standard.

If car bodies are to be maintained in good condition, they should be varnished at intervals varying from 6 to 15 months, according to the usage they receive. This is not so much for the sake of appearances as for preserving the paint and woodwork, which rapidly deteriorate when exposed to weather, the result being that the paint scales, and water gets into the cracks and joints of the wood. When this has once happened, nothing but burning off and entirely repainting the car will make it presentable. If a car is carefully kept, and varnished whenever necessary, repainting may be put off for five or six years. Cars also require a certain amount of carpenter work before they go into the paint shop, and repairs are frequently needed to floors, traps, windows, blinds, &c., not to mention those more serious repairs which may arise from collision or other accident. Besides the repair work to car bodies, the trucks require attention to an extent depending largely upon the type of truck adopted, as well as on the condition of the track and the care taken in running. Wheels and axles need renewing occasionally. We have already given details as to wheels. Of course the heaviest repairs will be required upon the motors and their accessories. When electric cars were first run, ten years ago, it was taken for granted that daily accidents would happen to the motors, but that is changed now. It is the usual practice to roughly examine the motors every night after the day's work, in order to see that the brushes are all right, and that the oil cups are filled. Every third day the motors are carefully examined, and once every four or six weeks the motors are opened up and taken to pieces and thoroughly cleaned. All the parts should be then examined, so as to make sure that they are in position and not likely to give trouble. Thus, as an example, the clearance between the armature and the pole face in the "G. E. 800" motor is $\frac{1}{8}$ in. On account of irregularity in the surface of the armature, and from take-up of wear which soon appears between the shells of the bearings and their seats, this distance is slightly diminished, so that $\frac{3}{32}$ in. is all the space that can be safely counted upon. The bearing on the commutator end, when worn so that it has $\frac{1}{16}$ in. play on the shaft end or $\frac{3}{32}$ in. on the pinion end, where the bearing is subject to a considerable wear on its upper side, should be replaced at once by a new bearing. The best form of bearing for this purpose is a solid bronze shell, not cast-iron lined with babbitt.

A repair shop should be made up of the following different departments:

The machine shop proper, in which all the various machine tools are

kept and the large repairs effected. Next, the smithy and forge, and, if the road is large, a small foundry should be located near the above two shops. Near the machine shop, but entirely separated from it by partitions so that no dust or dirt can enter, should be located the armature winding-room, where all the electric repairs will be made. This room should contain the side benches and small tools, and an oven for drying armatures. With the present system of winding in general use, a lathe for winding armatures is no longer necessary, as the coils are all wound on templates and then simply fitted on to the armature. There should be a carpenter shop and paint shop, the latter shop having a small space set aside and closed from all dust and dirt, in which car bodies can be varnished. Tracks should go through all these workshops. In an ideal repair shop a special room should be provided with car-pits extending all its length and fitted with a travelling crane, which would be utilised to lift the car bodies off the trucks, to lift out the motor, and to lift up the trucks so as to be able to run new axles and wheels underneath them. Besides the above, there should be a large supply-room in which the offices and tool-room should be located. Every armature, motor, generator and, in fact, every piece of machinery, truck or car body, should have an individual number, so that a record can be kept of when, why, and how often the various parts of the equipment have to enter the repair shop, and how much each individual piece costs to maintain.

The following is a list of the men required for the repair shop of a road running from 50 to 100 cars:

One foreman.	Six motor cleaners.
One assistant foreman.	Six car cleaners.
Two armature winders.	Two smiths.
Two fitters.	Two smiths' labourers.
Two fitters' labourers.	Two carpenters.
Six motor repairers.	Four carriage builders.

Four painters.

It sometimes happens that axles get bent. A device for straightening, in use at the repair shop of the Atlantic Avenue Railroad Company of Brooklyn, is worth mentioning. It consists of a heavy steel bar, 2 in. by 8 in. cross-section, suspended from a frame, two iron stirrups, and a screw-jack. The straightening is done while the axle rests in centres by screwing down on the nut of the jack. This can be placed between the hubs of the wheels wherever the greatest departure is found. Besides the tools and

men which have already been mentioned as necessary in a repair shop, a wrecking wagon able to seat five to eight men, and having a complete set of tools for getting any obstructions out of the way, or for temporarily repairing or pushing off the track any car which may have broken down, should be kept in readiness, together with a light tower wagon.

CHAPTER XIX.

THE WEST END STREET-RAILWAY COMPANY OF BOSTON, MASS., U.S.A.

THE street-railway system of Boston is the largest and most complete owned by any one company in the United States. It comprises over 272 miles of track, and owns 1,705 cars. It is largely owing to the enterprising spirit of the managers of this company that electric traction first took a foothold in America. Prior to 1888, all the street railways of Boston and its environs were operated by horses. All but 15 per cent. are now worked on the trolley system. The surface lines in Boston carry approximately 150,000,000 passengers yearly, and the suburban traffic of the steam railroads amounts to some 60,000,000 passengers per annum.

The West End Street-Railway Company is a consolidation of a large number of different companies running cars in Boston. The authorised common stock of this corporation amounts to 10,000,000 dols., of which 9,085,000 dols. have been issued and fully paid up. The authorised and issued preferred stock amounts to 6,400,000 dols. Debentures for 9,175,000 dols. have been issued. The lowest interest that has ever been paid on the common stock is $7\frac{1}{2}$ per cent.

This company now owns and operates five principal power stations, of which details are given in Table LXXXVIII.

TABLE LXXXVIII.—West End Street Railway Company's Power Stations, Boston.

—	Number of Engines	Horse-Power of Each Engine.	Style of Engine.	Number of Dynamos.	Kilowatts of each Dynamo.	Revolutions per Minute of Engine.	Diameter of Fly-wheel.	Weight of Fly-wheel.
							ft.	lb.
Central Power Station ..	6	2,000	Compound Corliss condensing	18	500	75	28	160,000
,, ,, (auxiliary)	10	250	,, McIntosh and Seymour.	40	50	250		
East Cambridge	3	2,000	,, Corliss condensing	7	500	75	28	160,000
Allston	4	300	,, ,, ,,	12	80	225		
East Boston	3	400	,, McIntosh and Seymour.	3	200	120	14	25,000
Charlestown	2	1,000	,, Corliss condensing	2	800	90	21	85,020

Of these, the most interesting is undoubtedly the Central Power Station, which at the time of its construction was considered a very

daring electrical engineering feat. If it were to be rebuilt now, its design would undoubtedly be greatly changed.

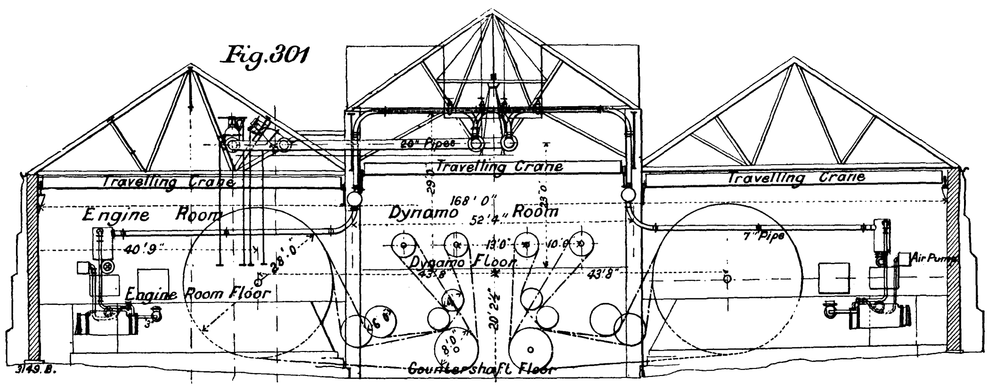
It was intended to have an ultimate capacity of 26,000 horse-power, of which, at present, only 12,000 are installed. There are six 2,000 horse-power Allis-Corliss engines of the compound condensing type, having three cylinders, respectively 23 in., 36 in., and 52 in. in diameter, with a stroke of 48 in. The working pressure is 160 lb. The piston of the tandem cylinders is coupled to one end of the crankshaft, and that of the third cylinder to the other. These engines make 75 revolutions per minute. The condensers are of the circulating type, and are located under the floor. The condenser pumps are vertical and of the Corliss type, and force cold sea-water to circulate through the condensers. The flywheel of each engine is 28 ft. in diameter, has a face of 10 ft. 7 in., and weighs 80 tons.

Countershafting is used on a very large scale in this station. More modern practice would undoubtedly dispense wholly with countershafts. The action of the friction clutches adopted, one of which is shown mounted on a generator, Fig. 302, has not proved satisfactory. To shut down one dynamo it is necessary to cut out the switches, but the armature has to be run on until the other three dynamos driven by the same engine can be stopped together by shutting down the engine running that section. It is certain that we do not overestimate the loss of power due to this countershafting if we take it as being 15 per cent. of the total power transmitted. Fig. 301 gives a section through the engine-room, and shows how the flywheels are connected by means of tension pulleys and countershafting to the generators. Each engine is coupled to a countershaft by means of two belts, 54 in. wide, and owing to the short distance between the centre of the countershaft and the centre of the flywheel, tightening pulleys have to be used. The countershafts are two in number, one for each set of engines, and are located under the floor of the dynamo-room. Each is 120 ft. long, and composed of three sections of 40 ft. each and 9 in. in diameter. A complete set of belt-tighteners is also provided for the belts driving the generators. The driven and driving pnlleys are 8 ft. in diameter, the former being mounted on a hollow shaft encircling the countershaft and connected to it by friction clutches. The three lengths of shafting are connected together by means of similar couplings. All these clutches are worked from the engine-room by means of a long shaft and handwheel. The dynamos are connected with the countershafting by means of 30-in.

belts. All the boxes of the countershafting are jacketed, so as to permit a cold-water circulation. Arrangements were made to enable each dynamo belt to be released from the pulley and supported on a cradle carrying rollers beneath each pulley, in order that any dynamo might be stopped while the engine is running.

The belt-tightening pulleys move horizontally, and the frame is supported on horizontal bars. These pulleys are moved by means of a screw passing through the box on which the pulley is mounted, the screw being operated by bevel gears from a vertical shaft leading from the handwheels on the dynamo floor above. The main belt tighteners are of massive design, and consist of a heavy upright cast-iron frame supporting two independent pulleys 6 ft. in diameter and 5 ft. face, situated on vertical sliding carriages,

Fig. 301



Cross Section through Main Power Station, West End Street Railway Company, Boston.

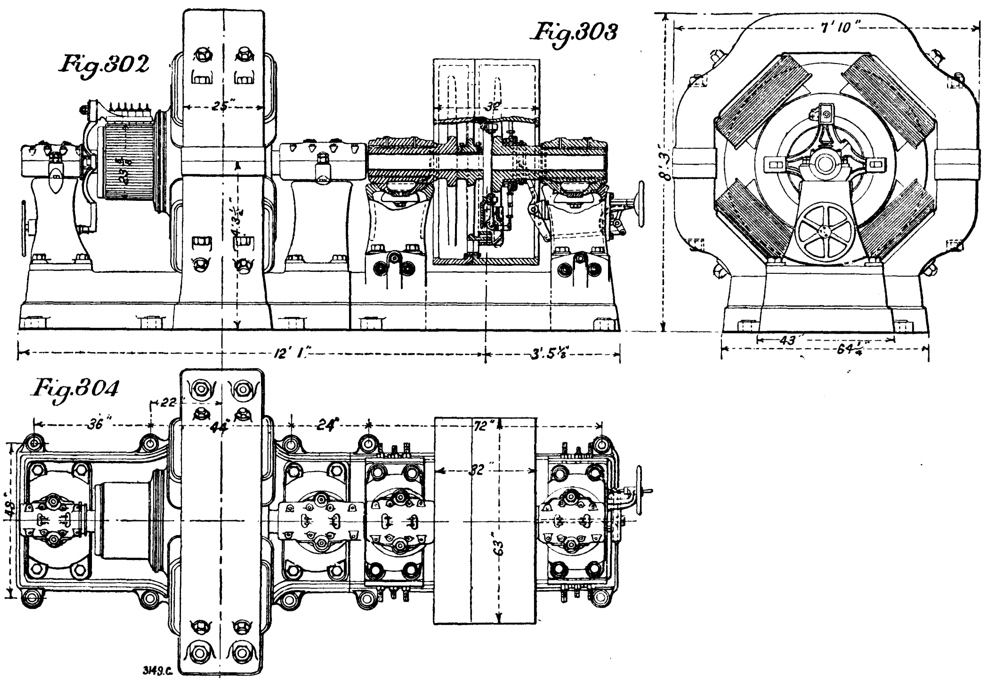
controlled by a heavy wormshaft operated in the basement by four 30-in. wheels.

There is a complete self-oiling system for all the machinery. The crude petroleum oil is received in tanks situated in a basement just outside the boiler-house. Thence it is pumped into the distributing-room, where it is refined and mixed according to the purposes for which it is to be used. In the engine-house, at a very low point, are discharging tanks into which the oil from the machinery runs, and whence it is pumped back into the distributing-room. The elevation of the oiling tanks gives the necessary head for the oil to pass through the brass tubes connecting them with the machinery.

Under the floor of the dynamo-room at either side is a feeder gallery, 4 ft. wide by 5 ft. deep, for the wires from the generator to the switch-house.

The generators are in four parallel rows running the length of the floor; four dynamos are driven by each engine. Each is approximately 9 ft. high, 8 ft. wide, and 16 ft. long, and weighs 35 tons.

Each generator (Figs. 302 to 304) has four bearings, and the pulley has a self-contained double-jaw clutch; the armature shaft has two bearings, and is entirely independent of the pulley shaft, but extends into the pulley without touching it, supporting a clutch ring, by which power is transmitted to the armature. The pulley is 56 in. in diameter and 32 in. face, and is split on the circumference and bolted together, each half being supported



BELT-DRIVEN THOMSON-HOUSTON RAILWAY GENERATOR, WEST END STREET RAILWAY COMPANY, BOSTON.

on a separated quill by a bearing. The generators are of the Thomson-Houston multipolar type, having four poles and a capacity of 600 amperes at a pressure of 600 volts, and at 400 revolutions. The armature is a Gramme ring, 48 in. in diameter, 25 in. long, wound in 180 sections. The capacity of the conductors is such that on an emergency 1,000 amperes could safely be carried. The shaft is 7 in. in diameter, and weighs, with the commutator, 9 tons. The depth of the core is 8 in.; it is carried on two spiders of gun-metal forced on to the shaft by pressure, and then keyed.

The insulation of the armature is tested with a 3,000 volts alternating current. The commutator is $24\frac{3}{8}$ in. in diameter, with a brush surface of 15 in., and weighs about 1,900 lb. There are 180 sections separated by mica; they are hard-drawn copper bars of 3 in. depth. The shell and caps of the commutator are of gun-metal. Each generator has a compound winding, the series winding being such that the over-compounding can be varied to give different compoundings at different loads. The generators are built to stand continuous running. The current is taken by four sets of carbon brushes, each set consisting of five double carbons. The brushes are moved by means of spurwheel and gear.

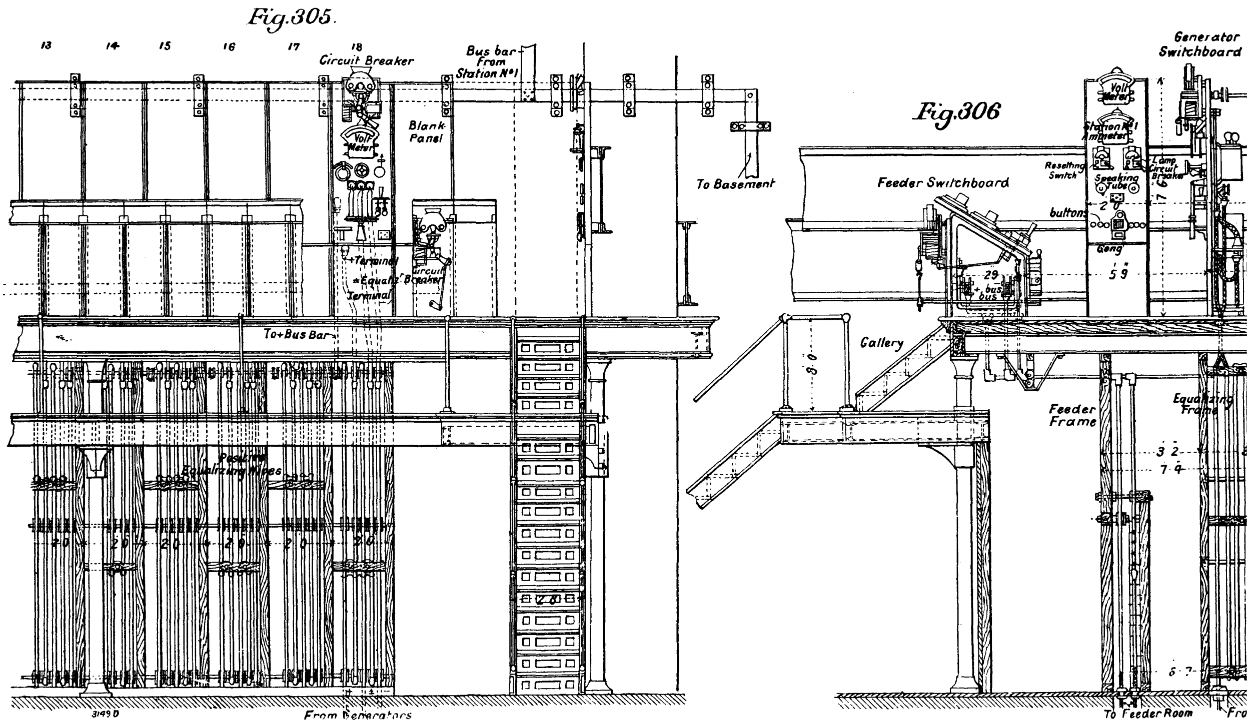
The wires from the dynamos are carried through the feeder galleries to the governing instruments for controlling and regulating the generators. Thence the wires pass into the feeder-room below, where the feeder circuits start, each feeder being provided with switch, ammeter, and lightning arrester. The feeders run in underground circuits, reaching various centres all over the city. Figs. 305 and 306 give some idea of the switchboard.

It will be seen from the drawing that the switchboard is elevated above the dynamo-floor and is divided into two parts, the one, the main switchboard, being vertical: the other, the feeder board, being inclined and located in front of the main switchboard, a pathway being left between the two. An attendant is always in charge of the switchboard so as to replace any circuit-breaker which may fly out, and to generally see that everything goes on as it should.

This Central Power Station, when finished, will be the largest in the world The immense installation, with its enormous weight of machinery, is situated on reclaimed land, which made the foundations very expensive. The surface of the ground is 17 ft. above mean low tide, and the whole of the foundations were excavated to this depth. The area occupied by the engine-room, economisers, and smoke-stack, was covered with piles 45 ft. long, 1 ft. in diameter, and 30 in. apart, close piling being also under the walls. In the engine-room the piles were cut off 5 ft. from low-water mark, and under the smoke-stack at low-water mark; under the chimney there are 810 piles, and under the engine-room 6,000. The whole excavation was then filled with concrete 6 ft. deep, consisting of five parts of broken stone, two parts of sand, and one of Portland cement. In the boiler-house, a sectional view of which is given in Fig. 307, each battery of boilers is supported on six stone piers, resting on five rows of piles, no concrete being used. The boiler-house has a single-span roof, and the engine-house a

triple-span ; the centre is supported by latticed columns. On either side of the boiler-house there are six batteries of Babcock and Wilcox water-tube boilers, furnishing 2,000 horse-power each; they are designed for a pressure of 200 lb. to the square inch.

Between the two rows of boilers there is a space 20 ft. wide, and in its centre a track for hand-trucks for handling coal. Under the centre is located a very complete system of mechanism for handling and removing the ashes. Opposite each fire-door is a shoot leading directly into this



ELEVATION AND SECTION OF SWITCHBOARD, MAIN POWER STATION, WEST END STREET RAILWAY COMPANY, BOSTON.

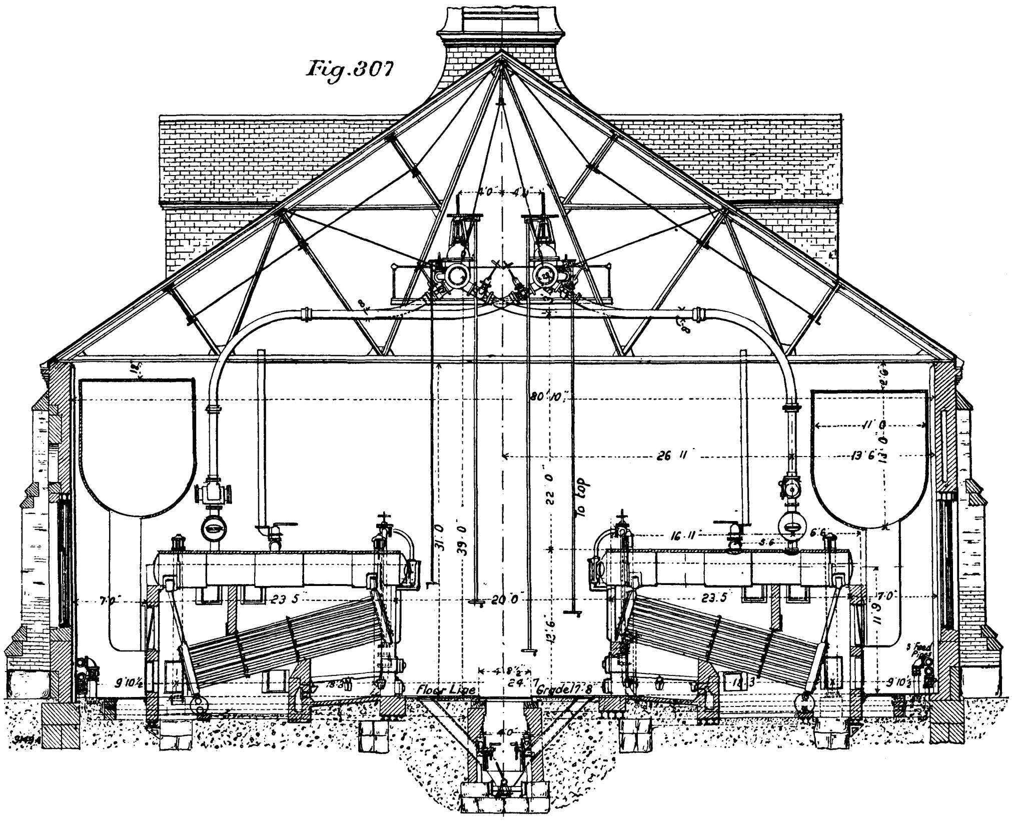
system, through which the ashes are dumped into a series of hand-cars, and transported on rails to the end of the pit ; here the ashes are emptied into a recess, in which moves an endless chain gear attached to pan conveyors. The boiler-house is equipped with a complete system of automatic coal-handling apparatus. The smoke-flues are supported from the roof-truss, and connect the boilers with the economisers.

The steam is taken from the drum of each boiler, and passes into an auxiliary drum of 30 in. diameter, which connects all three drums of each boiler. From each of these auxiliary drums two 8 in. pipes lead upward to

two 20-in. main steam pipes, leading to the engines, and supported by straps from the roof. The whole steam-pipe system is duplicated, one system being capable of furnishing the steam for all the engines.

The steam pipes are all of wrought iron, lap-welded; the joints are riveted, and the elbows are also of wrought iron bent to shape. The joints are made with steel flanges, single-riveted to the pipe, double-riveted to

Fig. 307



SECTION THROUGH BOILER HOUSE, WEST END STREET RAILWAY COMPANY, BOSTON.

each other, and caulked outside and inside. The clamp and main pipes are connected by heavy steel castings, riveted.

The smoke-stack is 252 ft. high over all, and the flue is 13 ft. 8 in. in diameter. Each engine has a separate foundation, with a wheel-pit between. The foundation consists of a substructure of granite, 12 ft. high and about 9 ft. wide at top. Upon this is built the superstructure of brick, 9 ft. high and 8 ft. wide, into which are set the capstones on which the cylinders and engine rest.

This is but a brief description of the interesting plant, which, with the other installations owned by the West End Railway Company, operates the largest electric railway system in the world. This plant was put down about five years ago, and it illustrates very forcibly the great faith which the company had at such a relatively early date, in electricity as a motive power for street railways.

The traffic which has to pass through some of the narrow streets of Boston may be gathered from the following figures. At the junction of Boylston and Tremont Streets, for example, 183 cars pass north and 197 south per hour during the busiest times of the day; and altogether during the day 2,114 pass north and 2,227 south. About a quarter of a mile above this point, in front of the Park-street Church, 2,600 pass north per day, and 2,135 south. On other streets, including parts of Washington Street, the number is nearly as large.

Records of voltage are kept in each station by a recording voltmeter, and are sent every morning to the head dynamo-man in the central power station, together with a chart of the ampere readings taken every fifteen minutes, from which the maximum and average ampere output is figured. The greatest output in the company's station on any day was on 10th December last, when the average for one hour (between 5 p.m. and 6 p.m.) was 22,860 amperes. The maximum was 26,540 when 720 cars were out of the car-house.

A very complete, though small, testing-room is situated about 150 ft. from the power-house, and is connected to it by underground and overhead leads. A Carpentier-Thomson reflecting galvanometer, encircled by an iron bell and fixed on a concrete foundation 15 ft. deep, is employed.

The room is also equipped with a D'Arsonval reflecting galvanometer. The Ayrton shunt is employed on the Wheatstone bridge, saving the necessity of thermometer readings. All instruments are placed on the ground side of the battery, which is insulated, so that any leakage of the instruments is a shunt to the galvanometer, and so does not have to be taken into account.

To check the swing of the galvanometer, two buttons, one of zinc and one of carbon, are placed on the key to one lead to the galvanometer, and an iron button on the other lead; and by touching the iron button with one finger and either the zinc or the carbon with the other finger, enough current is generated in either direction to bring the spot to the zero position.

This station is not only used for feeder testing, but also for the calibration of instruments, testing of armatures, insulation, &c.

The company has twenty-three electric car houses located in all parts of the territory covered by its lines. Each car-house is in charge of a separate foreman, and all the car-houses in any division, of which there are nine, are under the charge of a division superintendent. It is the aim of the company to standardise its apparatus, and to put all similar apparatus into a car-house by itself. The car-houses keep only a small stock of supplies on hand, and are furnished with anything which is required upon requisition to the main storekeeper. All apparatus is delivered from the storehouse by a freight car, which makes a tour of the car-houses once or twice a week. The car-houses are also inspected by a special man detailed for the purpose, who visits them once or twice a week, but at no stated hour.

Railway motors have been considered preferable to any other kind of power apparatus in the stations, because there is always somebody in every station who knows how they are operated. At each station there is also a large water-tank, holding from 20,000 to 40,000 gallons, for use in case there should be any lack of water in the city mains. This tank is heated in winter by steam pipes to keep it from freezing, and water in fire drill can be turned on in 30 seconds.

In all car-houses the offices, repair-room, boiler-room, &c., are located in a strip along one side, so as not to block up the entrance. The boiler-room and the oil-room are always of brick. The blacksmith's shop is always located near the boiler-room, and the stock-room near the pit-room. The sand-room is provided with steam-pipe grating, through which the sand is sifted, to keep it dry. There are as many entrance curves to each car-house as possible, to assist in getting out the cars in case of fire. This company does not believe in warming up the entire car-house, but always has the pit and wash-room warmed. This is a point the importance of which is not always appreciated by street-railway managers, especially those who formerly operated horse roads, and are accustomed to cold barns. Mechanics can work very much better and more expeditiously in a warm room than in a cold one, so that the saving in the amount of additional work secured alone would be more than required to pay for the heat. Flush transfer tables are mainly used in the car-houses, and are considered far superior to pit tables, as the free use of the tracks is never interfered with. A number of the largest transfer tables are operated by electric power, taking current from an overhead wire.

The West End Street Railway Company has at the present time over 3,700 men in its employ, but this number often rises to 4,500. The management of such an an army of employés, of course, necessitates very careful organisation. We shall consider this in later chapters on the organisation and management of street railways.

Increase in traffic has compelled the West End Company to practically re-model their main power station. The car house capacity of the company has been increased between October and July, 1895, to make room for 391 additional cars; and in June and July, 1895, 400 new motors were ordered.

The power equipment of the company has been increased by a new station at Charlestown, having a capacity of 1,600 kilowatts, and will be still further augmented by a new station to be erected at Dorchester. The Charlestown power station embodies a number of novel features in construction. This station is 93 ft. 8 in. long. The engine room is 63 ft. by 90 ft. 4 in., and contains two twin cross-compound Allis Corliss engines with cylinder dimensions 26 and 50 by 48 in. stroke. The receiver for the engines is vertical, and is located between the cylinders. The engines are so arranged that either high or low pressure cylinders can be used independently. The piping is short, and so arranged as to be practically in duplicate. The generators are "G. E." 800 kilowatt direct connected, and run at a speed of 90 revolutions per minute, giving current of 1,350 amperes each.

One of the most interesting features of the station is the steel fly-wheels used on both engines. The increasing frequency of fly-wheel accidents led the company to adopt as standard in future construction wrought steel instead of cast-iron wheels. The wheel is made of a large number of rolled plate segments, bolted together instead of cast in segments, and fastened together by bolts and rings. This construction permits a much greater velocity of rim than wheels made of cast iron. The speed at which this wheel will run is 90 revolutions, giving a speed at the circumference of more than a mile per minute. The weight is distributed as follows:

TABLE LXXXIX.—Showing Details of Steel Flywheels.

	lb.
Centre cast iron	20,000
Web	22,560
Rim	42,460
Total	85,020

The hub shown is 7 ft. in diameter with 21 in. bore, and it is fitted at one side with brackets to hold the armature of the 800 kilowatt generator. To the centre of the hub are connected the web plates, sixteen in number on each side, or a total of thirty-two, extending to the extreme outside diameter of the wheel. These plates are $\frac{3}{4}$ in. in thickness, and are faced along their edges so as to form a good joint. Outside of these segments are two circular plates, bolted through each segment by five $1\frac{1}{2}$-in. bolts, and through both plate and hub by three $2\frac{1}{2}$-in. bolts. The segments are braced by truss pieces, $\frac{3}{4}$ in. in thickness by 8 in., held in the centre by two $1\frac{3}{4}$-in. cross bolts, which act as struts. The centre of the rim between the web plates consists of nine 1-in. plates, each 8 ft. long and 20 in. deep, joining on the ends, as shown in the engraving. Each plate covers five joints of other plates, and no joints occur where the web plates join. Outside of the web plates surrounding the rim is a strip of 1-in. plate 14 in. in depth, rivetted through the rim by rivets every $11\frac{1}{2}$ in., and outside of this is another strip of 1-in. plate, 5 in. in depth, also rivetted through the rim by the same number of rivets. The heads of both these lines of rivets are countersunk. The wheels are fitted complete on the floor of the works of the manufacturers at Milwaukee before shipment, and all holes are drilled within $\frac{1}{4}$ in. of their size. When the wheels were erected in place at the power house, the bolt holes were reamed out and turned rivets driven in them.

There are three batteries of Babcock and Wilcox boilers of 500 horse-power each, each boiler containing 252 four-inch tubes 18 ft. long, and designed for a pressure of 180 lb. The boilers are faced with white glazed brick, giving a very handsome appearance. The economiser is of the Green type, and of 2,000 horse-power capacity. It contains 560 tubes, and is arranged with by-pass, so that it can be thrown in and out of circuit as desired.

The passage of the feed water is first into the primary heater, then into the feed pump, then into the secondary heater, then into the economiser. The primary heater takes steam from the engine exhaust, and the secondary from the feed pump exhaust.

The constant difficulties accruing in consequence of the clutch pullies and counter-shafts determined the West End Company to take out its old plant and numerous small units, and replace these by large direct-coupled sets. Owing, however, to the great interest attaching to the West End line, and to the elaborate countershaft system adopted, it has been thought just as well to describe its old historical plant.

The West End Company has recently commenced the reconstruction of the station to fit it more nearly to modern ideas. The plan contemplates the abolition entirely of the countershaft, and the use of direct-connected generators. This will be accomplished gradually by the fitting a 1,300 kilowatt direct-connected "G. E." generator to the shaft of each triple expansion engine, and by the erection in the space between each set of two engines, left vacant by the removal of the generator gallery, of a cross-compound Allis-Corliss engine, with 1,500 kilowatt generator.

The cylinders of the triple-expansion engines measured 23 in., 36 in., and 52 in. by 48 in. stroke, and ran at 70 r.p.m. Under the most economical conditions the engines were designed to develop a horse-power of about 1,000, and to work up to 2,000 horse-power as a maximum. Under the new conditions the engines are speeded up ten revolutions, so that they now make eighty revolutions, and with the increase in efficiency of the generators an increase in power of each of about 350 horse-power under ordinary conditions of working can be secured. The increase in efficiency by direct connection is estimated at from 10 to 12 per cent.

The triple expansion engines were equipped formerly with cast flywheels, which were employed for driving the belts. By removing this wheel sufficient space was secured on the shaft to mount a plate flywheel, which occupies only 40 in. of shaft room, and also a 1,300 kilowatt "G. E." generator. The old flywheel weighed 157,000 lb. The new flywheel weighs only 120,000 lb., and measures 16½ in. across the face. The size of the shaft was increased from 18 in. to 24 in., and a new pillow block was supplied strong enough to sustain this additional weight.

The cylinders of the new cross-compound engine measure 32 in. and 62 in. by 60 in. stroke, making the total capacity in power when the station is completed of 12,300 kilowatts, with no increase of floor space. The former output was about 7,500 kilowatts. The new compound engine is fitted with a plate steel flywheel, similar in general construction to that in use in the Charlestown power station. It is 24 ft. in diameter, and weighs 150,000 lb., and runs at a speed of 75 revolutions per minute.

CHAPTER XX.

CHICAGO CITY RAILWAY.

UNTIL quite recently the City of Chicago would not allow trolley lines within its boundaries, but with the universal American acceptance of this mode of traction, Chicago has joined in the march of progress, and there are as many trolley lines there at the present day as in any other American city. The Chicago City Railway Company owns horse and cable roads as well as electric, its total amounting to 162 miles of track, of which 35 miles are cable, 74 miles are electric, and the remainder, horse. The track is standard gauge, 4 ft. $8\frac{1}{2}$ in., and 100-lb. girder rails are used. There are 218 electric motor cars, and 1,221 ordinary cars, which are utilised to make up trains drawn by motor cars. The electric power-house is built of red brick, one storey high, with a trussed roof. From without the building has the appearance of having two storeys, although in reality it has but one. The interior of the engine-room presents a very handsome appearance. It is finished in red brick, and wainscoated to a height of 7 ft. with enamelled white tiles. Its dimensions are 90 ft. by 128 ft. At present there are only four engines and four dynamos installed. These engines drive in pairs on to built-up flywheels 18 ft. in diameter and weighing 50,000 lb.

The hub of the flywheel is pressed on to the shaft. Each arm (there are 10 in each wheel) is recessed 4 in. into the hub, the flanges are then securely bolted to the hub with heavy reamed bolts fitted to reamed holes, and each segment of the rim is bolted to the arm with four heavy bolts and keyed with tapered side keys. The rim of the wheel is grooved for 21 wraps of $1\frac{1}{4}$-in. rope. The connecting-rods are solid steel forgings with cast-steel boxes filled with Magnolia metal. The crankpins are 8 in. in diameter by $8\frac{1}{2}$ in. long, and the crossheads are of steel with removable pins, 7 in. by $7\frac{1}{2}$ in. The piston-rods are 5 in. in diameter. The crank-shafts are hammered steel forgings 14 in. in the bearings and 16 in. in the hub of the wheel. The bearings in the frame are built to accommodate the 14-in. shaft, and are 26 in. long. Metallic Golden Rod packing is used

throughout the engines, and Wheelock piston packing is in all the pistons. The discs are of cast steel, and are of a new and unique form.

The engines are of the Wheelock type, and furnished with Hill valves. These engines have unusually heavy crossheads and crankpins, all parts being made sufficiently strong for larger cylinders than those now employed the idea being that if additional power should be required, larger cylinders can be substituted. The floor around the engines is covered with tin, from which waste oil can be readily removed: a very desirable feature, and one which facilitates the labour of keeping the engine-room in a cleanly condition, this station being noted for the attention paid to this important detail. The engines run at 100 revolutions per minute at 100 lb. boiler pressure. During the heavy traffic called for by the World's Fair in 1893, each pair of engines frequently developed 1,400 horse-power, the size of the cylinder being 24 in. in diameter by 48 in. stroke.

The remaining part of the floor is covered with polished oak, and the whole station is kept in absolutely perfect order. Very commodious bath-rooms, lavatories, and dressing-rooms are provided for the engine-room staff. The engines are coupled in pairs to the same shaft, and each pair drives, by means of the continuous ropes, two Westinghouse multipolar generators of 700 horse-power capacity, the armature of each generator being coupled to the driving pinion by means of friction clutches of the usual type. The transmission ropes are of cotton, $1\frac{1}{4}$ in. in diameter, and a portion of the wraps is led over an idler from the armature pinion, forming a compound wind, in order to equalise the friction contact with that of the driving sheave. The tension sheave is mounted in a horizontal position on a truck, which travels back and forth on a track attached to the ceiling, and to which the two strands of the rope are led over perpendicular guide pulleys supported from the ceiling. A tension of only 150 lb. is employed, and this weight is suspended next to the wall at the back of the station. A railed-in platform, suspended from the ceiling, gives ready access to the tension car and guide pulleys (Figs. 308 and 309).

The boiler-room is 56 ft. by 158 ft., and is very well lighted and ventilated. There are to be, in all, 14 Mohr tubular boilers, 72 in. in diameter by 20 ft. high, and of 300 horse-power capacity each. Of the 14 boilers, seven only have been installed so far, and Murphy automatic stokers are fitted to them. The coal is delivered from an overhead tank, having a capacity of over 400 tons. A coal conveyor brings the coal from this tank, and feeds it into the automatic stokers. The smoke-stack is 170 ft. high,

built of brick, and situated in the centre of the battery of boilers. It has a 10-ft. flue throughout its entire length, and forms the outer wall to the boiler-room. The gases from the boilers are led to the stack by means of iron breechings. Feed-water heaters are used which will deliver water at 212 deg. Fahr. to the boilers, which are each fed by two Schaffer and Budenberg exhaust steam injectors. A Worthington duplex pump is also installed, as a supplement to the injectors. The water is supplied direct from the city main, and a storage tank is situated under the floor which has a capacity of 90,000 gallons.

The rear of the boiler settings comes within a few feet of the partition wall between the engine and boiler rooms, and in order to provide for the removal of the mud drums through which the feed water is led, openings have been provided in the partition wall,

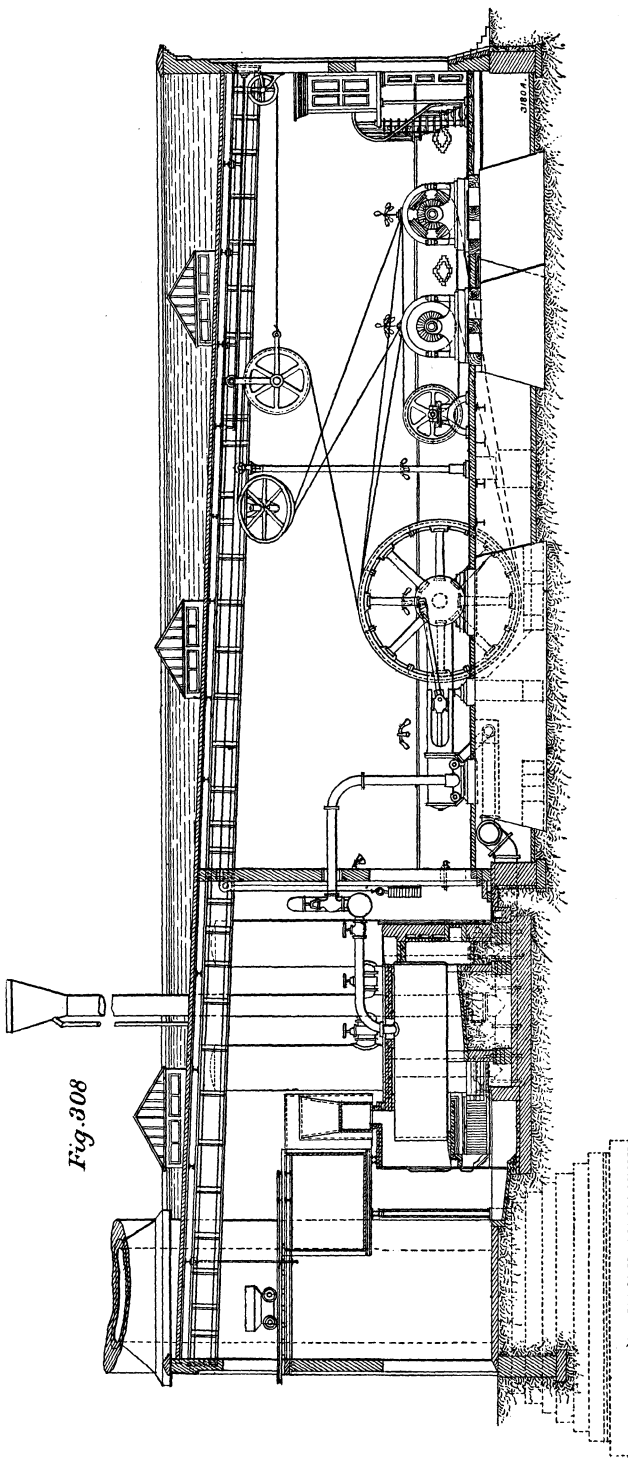


Fig. 308

SECTION THROUGH POWER HOUSE, CHICAGO CITY RAILWAY COMPANY.

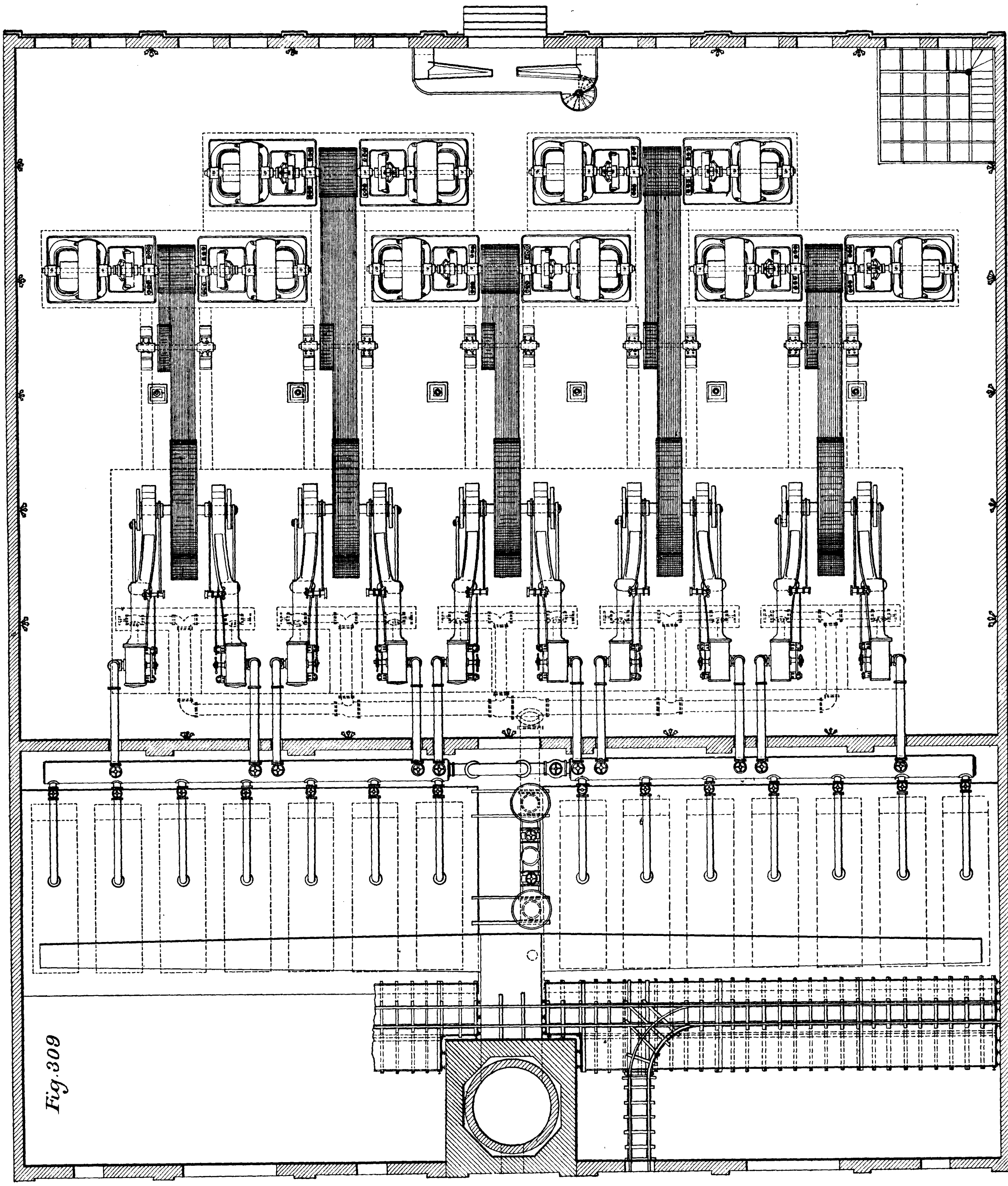


Fig. 309

Plan of Power House, Chicago City Railway Company.

These openings on the engine-room side are provided with doors, and have been converted into cupboards for the storing of waste, tools, and supplies, the shelves of which can be readily taken out when it is necessary to remove the mud drums. To prevent the excessive heating of the rear flue doors, a sheet-iron shield is placed inside the door, which is provided with a handle, so that it may readily be removed.

A very complete system of piping is employed. A 30-in. drum, 53 ft. in length, extends over the entire battery of boilers, which are connected by means of an 18-in. copper gooseneck from the 30-in. drums. Steam is taken to each engine by means of a 10-in. pipe having a 10-in. angle valve placed next to the drum. Copper joints and elbows are used exclusively. The switchboard is located above the door on the street side of the engine-room, and is supported by a balcony on which an attendant is constantly stationed to watch the instruments. One section of this switchboard controls the station apparatus, while the other controls the lines. Access is had to the balcony by means of a winding staircase. A separate lighting plant is used for lighting the engine and boiler rooms. This is done by 10 arc lights and 16 incandescent lamps.

An interesting feature of the electrical equipment of this station is the type of water-tank lightning-arrester adopted. These are placed in the basement of the station, and situated so as to be readily switched in and out of circuit. The water is contained in wooden tanks, which are about 2 ft. in length, 1 ft. in depth, and are provided with intake and outlet pipes, so that when in operation a current of water is constantly flowing, which prevents excessive heating. The tanks are thrown into the circuit by means of plug switches, and are readily connected whenever a storm approaches, the loss from leakage while in service being very small. The conductors between the tank and machinery are provided with choking coils made of heavy copper rods. The station has suffered no damage from atmospheric discharges since it has been in operation. These water-tank lightning-arresters have an approximate resistance of 80 ohms each, and take about 20 amperes when put in circuit. There are three banks of lightning-arresters between the generators and the overhead line, two sets being on the generator side and one set on the trolley side. Each dynamo runs a small Westinghouse air pump, which forces air at a pressure of 60 lb. per square inch on to the commutator and into the armature, serving to keep these perfectly free from dirt and dust. The average voltage at the station is 525 volts. Among the station appliances is a Perfection oil

purifyer, manufactured by the Perfection Oil Purifying Company of New York, in which the oil is filtered, and by its use a great saving is effected, one barrel of lubricant only being sufficient for oiling the engine and other parts—with the exception of the crosshead and crankpin—for 21 days, a little new oil being added each day. It requires about two barrels of oil a year for the bearings of the four generators, the self-oiling boxes being of sufficient size to hold a supply for 90 days.

The nominal capacity of this station will be, when completed, 10,000 amperes at a pressure of 500 volts. At the present moment the average daily current is 450 amperes with 55 motor cars running, the maximum being 1,000 amperes, and the minimum about 200. The average voltage is 515 volts, but it varies between 500 and 525 volts. The average speed of the cars on these lines is 16 miles an hour.

The motor equipment of the cars is chiefly of the Westinghouse type, and so far the armature repairs have been very slight, one man easily doing all the winding, &c. A new device to facilitate quick repairs at the car barns is noticeable. The hydraulic trucks which operate on tracks in the bottom of the pits, and which are employed for removing the armatures, are in some cases provided with a small box which rests on the platform, having on its upper surface parallel wooden rollers about 3 in. in diameter, which allows the armature to turn as it is being lowered from its bearings, so that the pinion will free itself from the gear. Another useful appliance consists of a tripod, with legs composed of $1\frac{1}{2}$-in gas-pipe, which is employed for lifting the motor to remove a broken axle or wheel. In case of an accident of this kind, the tripod is placed on the floor of the car, when by means of a block and tackle the motor may be lifted into position, the attachment being made by an eye-bolt screwed into the motor field, a hole being drilled and threaded for the purpose. With this device a crippled car can be returned to the barn either by power from its other motor or can be pushed in by another car. To prevent the pulling down of the overhead construction by the trolley pole, a guard has been devised which consists of horizontal rods, and which is attached to the base of the trolley harp, and extends both sides of the wheel. In case the trolley wheel leaves the wire, the guard comes into contact with the trolley, and prevents the wheel from engaging with the span wires. As a means for holding up the trapdoor of the car when the motors are to be inspected, a button composed of a metal plate having an offset, and attached to one end by means of a bolt to one of the floor timbers, is provided. This

is readily turned up in position when the door is opened, where it holds it firmly.

The Chicago City Railway Company was chartered on February 14, 1859, for 99 years. The common stock authorised and issued up to January 1894 amounted to 9,000,000 dols. The first mortgage bonds were issued for 4,619,500 dols., with interest at $4\frac{1}{2}$ per cent. The ordinary 100-dol. shares of the Chicago City Railway Company are now quoted at 314 dols.

The immediate control of the car men is assigned to a chief supervisor with three assistants, two of whom, with the chief, constitute a board or commission, which meets every morning to receive and act upon the reports of the inspectors and the complaints of passengers, and who sit once a week to try such employés as may be ordered before the board for any cause. In case an employé is ordered to report before the board, he is understood to be suspended for that day.

The number of car employés on this system is now 1,700, and out of this number there are, on an average, about 40 punishable offences reported each week. The daily complaints from passengers run from five to eight, and about 250 complaints a week of a more or less serious nature come before the board. Notwithstanding the falling-off of traffic after the close of the World's Fair, very few of the extra men were discharged. No new car employés, however, are being hired, and the force is being reduced only by discharges for cause, the policy of the management being to give employment to as many extra men as possible to help them to bridge over the hard times, notwithstanding the fact that the wages paid by this company are higher than those paid on any other line in the country. The inspectors, while on duty, are stationed at different points of the line, and are constantly watching the movement of the cars, and on the look-out for any infringement of rules by employés. The amount of coal burnt per day in this station amounts to 25 tons.

CHAPTER XXI.

CITY AND SUBURBAN RAILWAY COMPANY, BALTIMORE; CASS AVENUE AND FAIR GROUNDS ELECTRIC RAILWAY, ST. LOUIS; AND OTHER TYPICAL POWER PLANTS.

POWER PLANT OF THE CITY AND SUBURBAN RAILWAY COMPANY, BALTIMORE, MD.—The ultimate capacity provided for in this plant is 5,000 horse-power. The present requirements call for a maximum of 3,000 horse-power, leaving the balance of the plant to be installed as the demands of the road increase. The contract provided that the engines should develop one indicated horse-power per hour on $14\frac{1}{2}$ lb. of water.

Referring to the plan, Fig. 311, it will be noted that the boilers are arranged in one battery with ample firing space in front. Overhead coal storage is provided, the coal being taken from boats at the wharf alongside of the power-house, and elevated into overhead bins, whence the coal is discharged by gravity into Rooney automatic stokers. The ashes drop from the furnaces into iron pockets, from which they are discharged into conveyor buckets that carry the residuum out of the power-house into outside ash-bins. The boilers are of the Campbell and Zell water-tube type. The Hunt Conveyor system, already described in these pages, is used. Fig. 310 is a transverse section, and Fig. 311 a plan of this station. About 6 ft. from the rear of the boilers a brick fire wall extends from sub-cellar to roof, with only one iron fire-door communicating with the engine-room, thus enabling a complete separation of the boiler-room from the engine and generator-room to be made in case of need. A firebrick-lined smoke flue resting on irons, the ends of which are supported on the rear boiler and fire wall, connects each boiler into a self-supporting steel firebrick-lined stack 9 ft. in diameter and 150 ft. high, suitable for one-half the ultimate capacity of the plant. This stack rests on a solid masonry pier 18 ft. square and about 32 ft. high. A main steam header, common to all the boilers and engines, runs along the boiler-room beside the fire wall, supported on iron brackets and rollers to allow for expansion and contraction. Into the bottom of this header, branch pipes from each boiler are

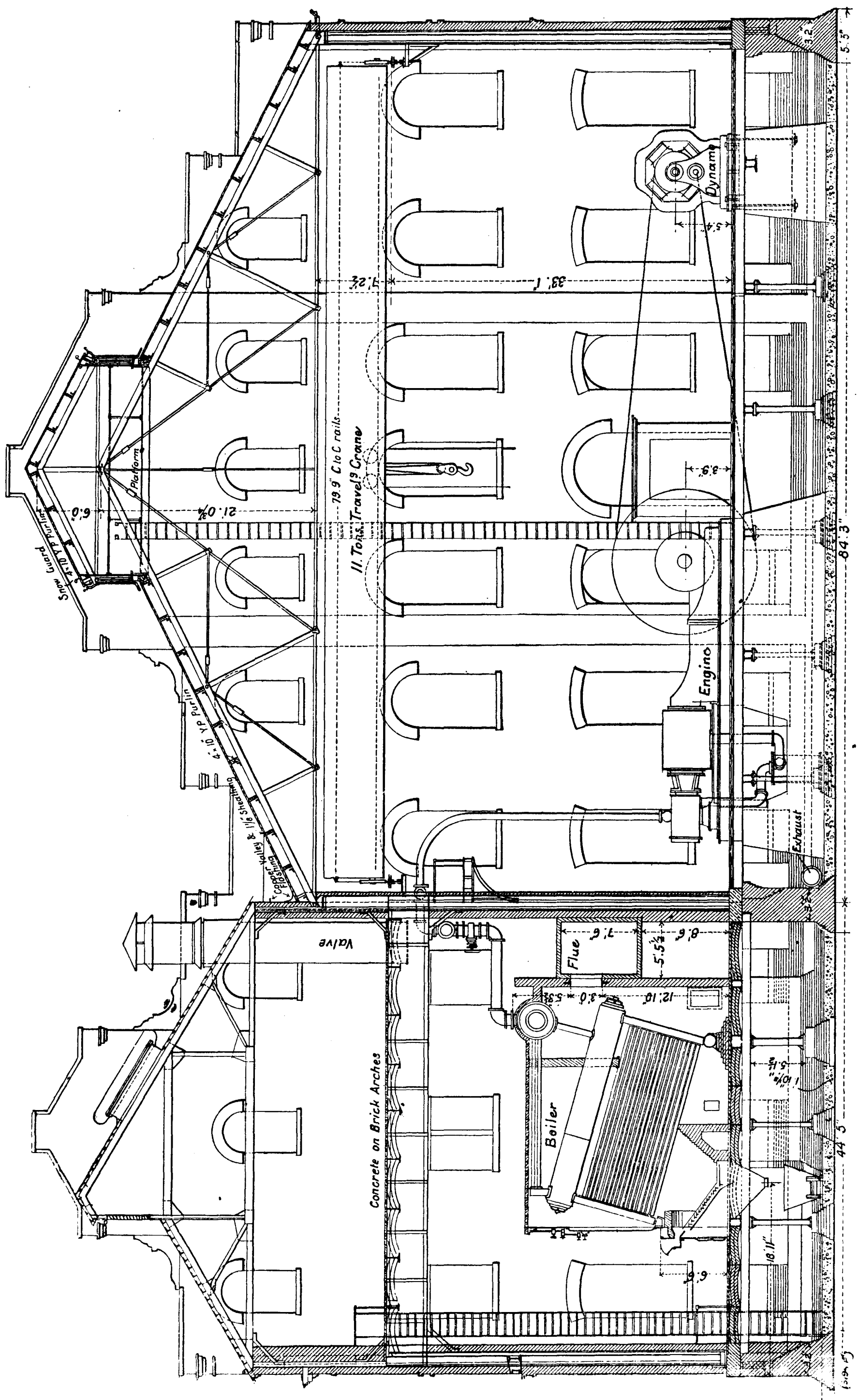


FIG. 310. CROSS SECTION THROUGH POWER STATION OF CITY AND SUBURBAN RAILWAY COMPANY, BALTIMORE.

connected, and removable bronze seat gate valves are located in each branch immediately under the header. This main is of ample size for the ultimate capacity of the plant, being made up of pipe 14 in. in diameter with flanged joints. It is divided into sections by means of gate valves as shown, to permit of repairs to joints, etc., in any section without interrupting the operation of the balance of the plant. From the top of this main header, branch pipes connecting to each engine are run. Immediately after passing through the fire wall, each branch is fitted with a gate valve in addition to the throttle in the pipe where it meets the engine cylinder.

Immediately over the throttle valve, steam separators are placed, the drain for these separators being the steam supply pipe for the steam jackets on the engine cylinders, and the reheating receivers, which are placed between the high and low pressure cylinders of each engine. The outlet of the supply pipe is connected to an automatic drain pump and receiver, which not only insures a constant and complete draining of the water of condensation, but also a continuous circulation of steam through the jackets, thus preventing an accumulation of water and giving the proper heating results in the cylinders and receivers. Underneath the main steam header is run a secondary small drain pipe connected into the steam main at short intervals. This drain header is connected into the automatic drain pump and receiver. In fact, all the live steam drips and drains in the entire plant are connected in the combined pump and receiver to insure a constant and complete draining of the system. This water of condensation is returned from the pump and receiver directly into the boiler-feed system, as it has a temperature of nearly 312 deg., which temperature would be lowered if a hotwell or any system other than the combined pump and receiver were used.

All pipe fittings, flanges, etc., are made of extra thickness, and are held together by large bolts on close centres; nickeline metal is used for joint packing. All live steam valves are of the Chapman extra heavy removable bronze seat gate type. This make-up of piping has been found necessary where pressure of 125 lb. and higher are used.

The engines are of the McIntosh and Seymour tandem-compound automatic horizontal type, having high-pressure cylinders 20 in. in diameter, low-pressure cylinders 36 in. in diameter, and 36 in. stroke. Each engine with 125 lb. initial steam pressure, $\frac{5}{16}$ cut-off, in high-pressure cylinders 24-in. vacuum, and running at 103 revolutions, is rated to develop the economical power required to drive a 525-kilowatt General Electric

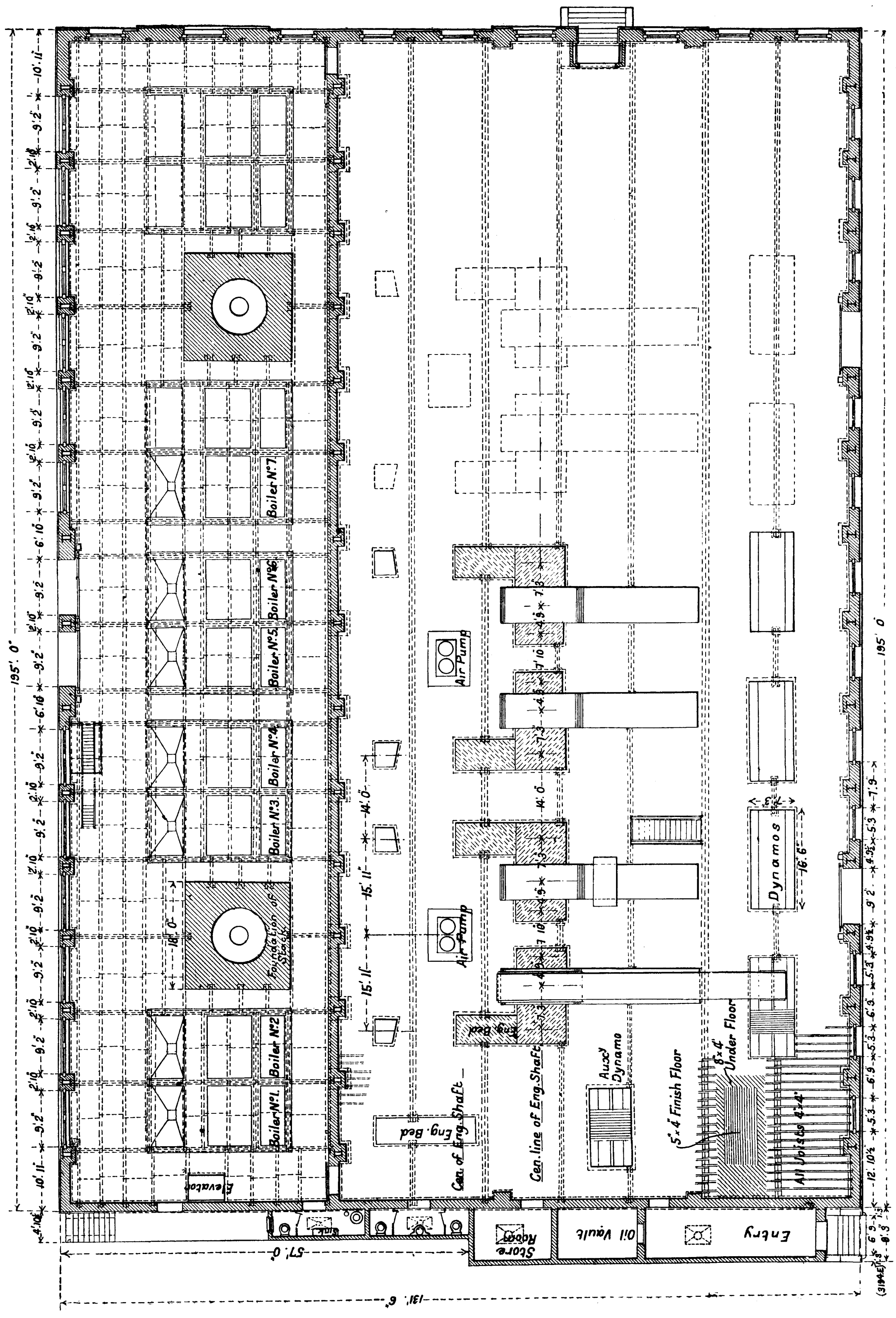


Fig. 311. Plan of Power Station of City and Suburban Railway Company, Baltimore.

Company's belted generator. The speed of the generators is 350 revolutions with pulleys 56 in. face, 49 in. in diameter, requiring each engine pulley to be 14 ft. 1 in. in diameter and 60 in. face. Belt centres 38 in. Figs. 312 to 315 give views of this engine. They are worthy of more extended description, as in the Ridgewood Power Station of the Brooklyn City Railway Company, Brooklyn, New York, three of 800 horse-power each, are developing an efficiency in excess of any engine heretofore used on railroad work in the United States, not excluding the well-known Corliss type. Six engines of this make, rated at 800 horse-

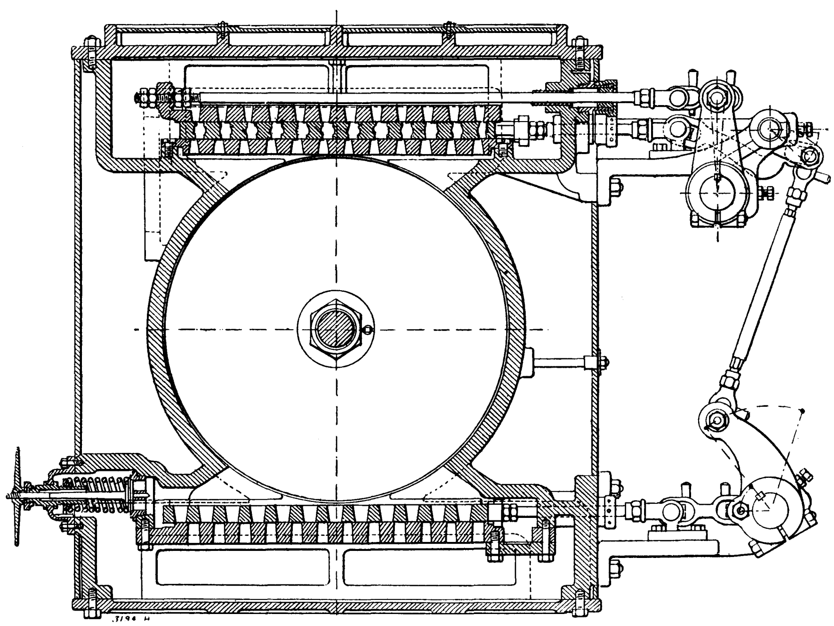
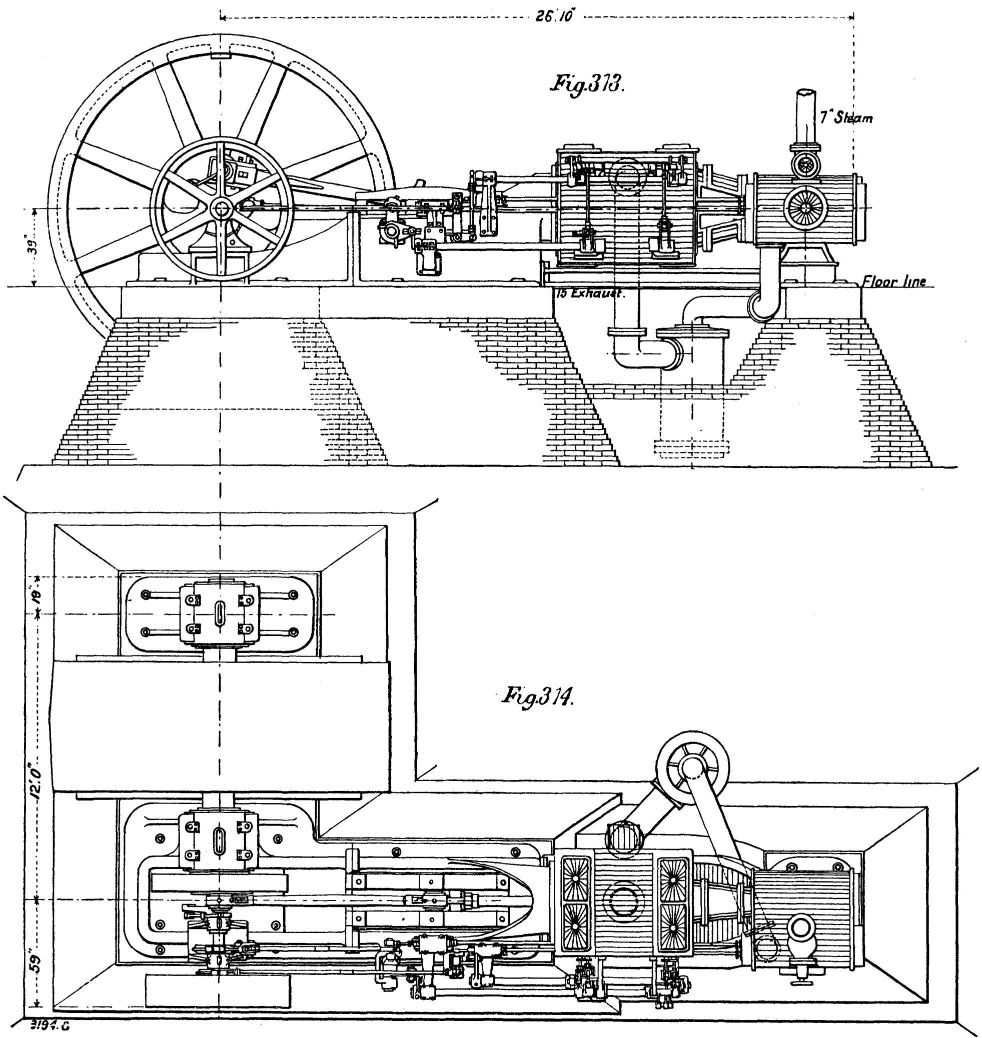


FIG. 312. McINTOSH AND SEYMOUR ENGINE. CROSS SECTION THROUGH CYLINDER, SHOWING GRIDIRON VALVE.

power each, are employed by the Cincinnati electric lines. The weight of each engine is 175,000 lb. The shaft is 16 in. in diameter, made of hammered iron. The cylinders are placed tandem, the high-pressure cylinder behind the low, the iron connecting head between the two being made sectional and removable, to give access to the low-pressure piston without disturbing the high-pressure cylinder or its piping. The piston-rod gland in the front and back heads of the high and low pressure cylinders, instead of being of the usual type, is a metallic sleeve babbited with steam-tight joints against the cylinder heads; this sleeve entirely incloses the piston-rod, and serves not only as a continuous packing to the rod, but also in a measure

as a crosshead holding the heavy pistons centrally in the cylinders, and preventing their dragging on the lower cylinder surface, as is the case where short glands are used, which quickly wear down. The high-pressure cylinder of each engine is provided with a live steam jacket, both cylinders being lagged with iron panel-work, backed with mineral wool. In the



McINTOSH AND SEYMOUR BELTED COMPOUND ENGINE.

connection between the high and low-pressure cylinders is placed a steam coil heater or receiver, the purpose of which is to dry the steam, and put it in condition to do its best work before going into the low-pressure cylinder. The bed-frame proper is extended back under both cylinders, the high-pressure cylinder being supported by a heavy cast-iron pedestal resting on

the extended box. This gives a rigid and continuous support to the entire engine, exclusive of the outboard bearing. The high-pressure cylinder is fitted with double piston-valves, the cut-off valve being known as the riding auxiliary cut-off, which is operated from the automatic shaft governor, the main valve working with a fixed cut-off. The low-pressure cylinders are fitted with double flat valves at four points, these valves being of the grid-iron type (see Fig. 312). The induction valves are double, the exhaust valves single. The exhaust valves are operated from the same eccentric-rod as the main valves, and by means of a jointed connection between the valve-rod and the eccentric strap, the angularity common to ordinary eccentrics is avoided, giving a uniform cut-off to the valve on both ends. By the use of this valve gear, the clearance in the low-pressure cylinder is reduced one-half below the lowest attainable clearance in the Corliss type of engine.

One peculiar and valuable feature in this engine is the method of driving the valve gear. The eccentrics, instead of being placed on a large diameter main shaft where heating would be bound to occur, due to the high peripheral speed of the shaft, are mounted, together with the automatic shaft governing wheel, on a small diameter auxiliary shaft which is connected to the crankpin of the engine by means of a drag link.

This, it is claimed, does away with all danger from heating, and maintains the valve driving shaft in perfect alignment, irrespective of the wearing of the main shaft. The main and outboard bearing pillow-block is fitted with oil chamber, filter, and small oil pump driven from the shaft. This method gives a continuous and ample supply of oil to the main bearings. The outer ends of the bearings are fitted with return oil grooves, to prevent the oil from working out from the end of the shaft.

The lower half of the bearing in the main outboard pillow-block is of the removable shell type, instead of being solid babbit hammered into the pillow-block itself. When it is necessary to renew the box, the weight of the shaft, wheel, or armature, if carrying a direct-connected generator, is taken off the main bearings by means of jacks, after which the removable shell bearing is rolled out, and a new one rolled in its place without disconnecting the engine in any way. Each pair of engines has one Wheeler "Admiralty" vertical condenser, common to the two engines. The cylinder dimensions of the condensers are 16 in. and 31 in. by 21 in. They are brass-lined, with brass pistons and rods, and arranged for use

with salt water. A double set of Blake feed pumps, of the duplex type, is also provided with the plant.

As will be noted on the section, the distance between the sub-cellar and lower side of engine-room floor is 8 ft. This gives a clear under-floor space (excepting the room occupied by the condensers and foundations) for laying and easily examining injection, exhaust, and waste pipes, all of which are placed under the engine-room floor, great care being used that the exhaust from the engine shall run horizontally to the condenser, and that at no point shall the injection pipe be above the level of the injection

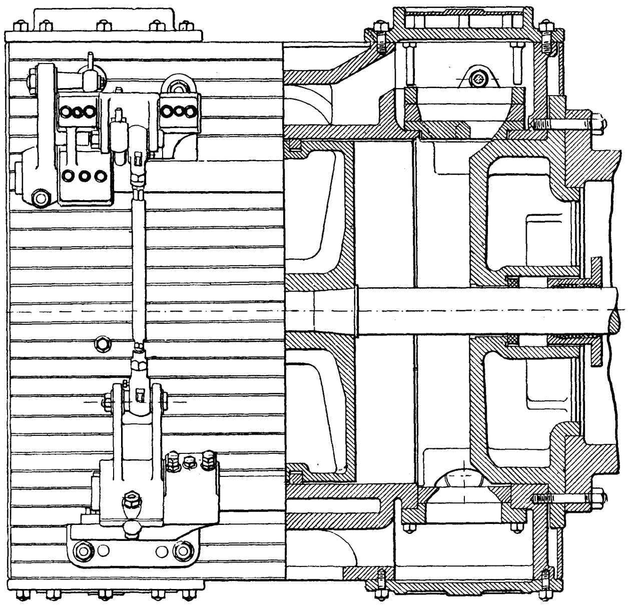


FIG. 315. McINTOSH AND SEYMOUR ENGINE. LONGITUDINAL SECTION THROUGH CYLINDER.

inlet in the condenser; in order to avoid the forming of any water pockets from which the water would be drawn back into the low-pressure cylinder under light load conditions, in which case the low-pressure cylinder acts as an air-pump.

The exhaust from each engine is carried into a main header, every engine branch exhaust being fitted with a gate valve, and each pair of engines exhausting as shown into one main header, which is fitted with a steam-tube heater near the junction of the pipe and condenser. In this way the heat in the exhaust steam (about 125 deg.) is utilised for heating the feed water, as the feed water is first passed through this heater, from

which it goes to a secondary or auxiliary heater placed in the boiler-room in front of the stack and near the feed pump. Into the auxiliary heater the high temperature exhaust steam from the condensers and feed pumps is turned, imparting to the feed water a temperature of from 200 deg. to 210 deg. This temperature would not be reached if hotwells were used.

FIG. 317.

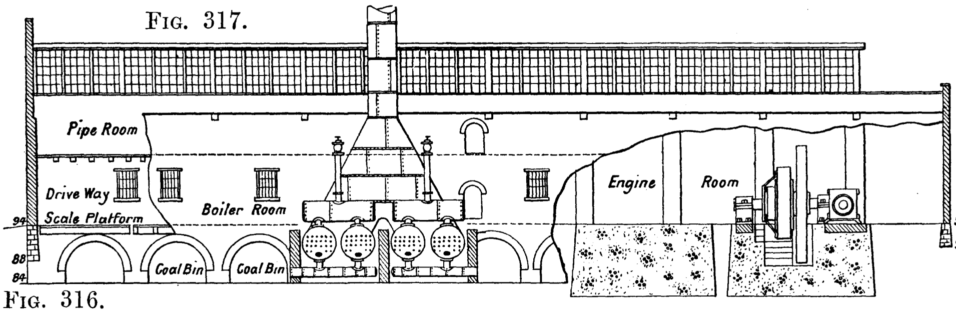
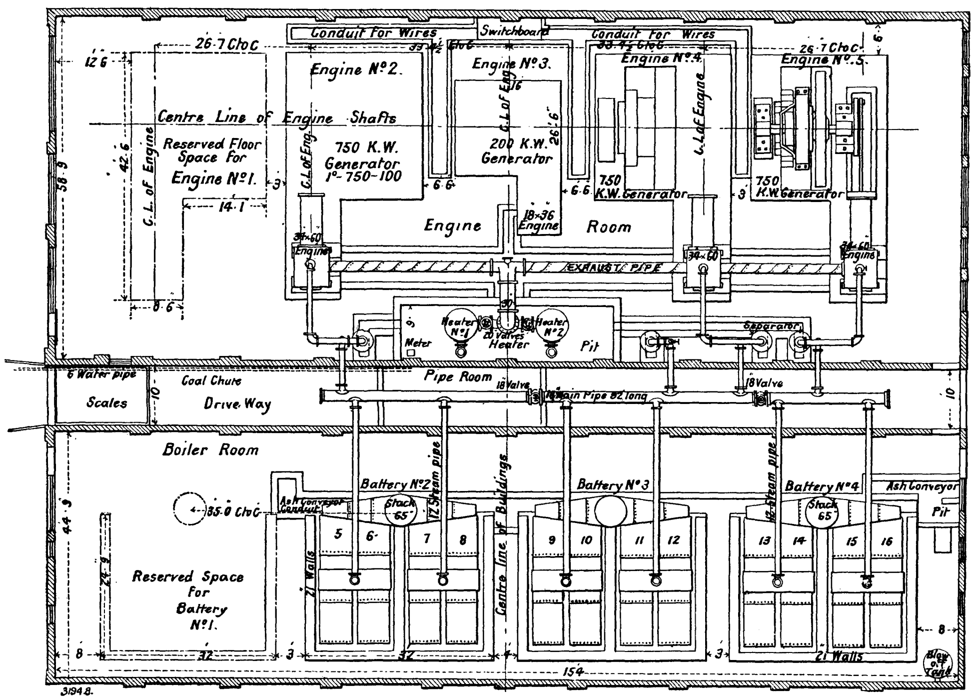


FIG. 316.



LONGITUDINAL SECTION AND PLAN OF CASS AVENUE POWER HOUSE, ST. LOUIS.

The size of the exhaust heaters is 50 per cent. of the horse-power of the engines. The size of the auxiliary heaters is 50 per cent. of the capacity of the exhaust heaters.

In addition to the main exhaust from each engine to the condenser, it will be noted that the branch exhaust from each engine before reaching the

main header is fitted with a secondary branch exhaust connecting into a main header 18 in. in diameter, and opening to the atmosphere. In each engine branch atmospheric exhaust is placed a Wheeler automatic atmospheric valve. The purpose of this valve is that in a case of loss of vacuum or other interruption to the condenser, this valve will automatically open, changing the engine from condensing to non-condensing without interrupting its operation, and the engine still remains in condition to carry its full load by cutting off later. When the condenser is again put in operation, the valve automatically closes to the atmosphere. No condensing plant is safe without this arrangement.

It may be interesting to know that this entire plant, power-house and all, is located on a dock or pier projecting into the bay. This necessitates carrying the entire weight of building and contents on piling. The piles

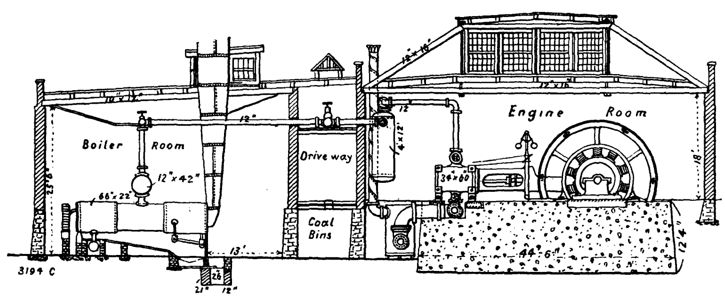


FIG. 318. CROSS SECTION THROUGH CASS AVENUE POWER HOUSE, ST. LOUIS.

are driven on 3-ft. centres, then capped by 12 in. by 12 in. timbers, which again are covered with a double thickness of 4-in. plank, laid diagonally, and the joints caulked. The top of this floor is on a level with high tide, Over the floor is laid 12 in. of concrete, into which the building walls and foundations for the machinery project. The outside walls are water-tight to a height of 9 ft., to provide against a possible 8 ft. rise of tide. This brings the door openings into the building about 1 ft. above the street grade. The company owns 61 miles of track operated electrically, over which 135 motor and 30 trail cars run. Its authorised capital stock is 3,000,000 dols.

CASS AVENUE AND FAIR GROUNDS ELECTRIC RAILWAY, ST. LOUIS, MISSOURI.—The interest of this station is chiefly due to the fact that it was one of the first to adopt (1892) direct coupled units of any considerable size at a time when American engineers were still great advocates of belted machines. There are several other companies in St. Louis operating

electric, cable, and horse lines aggregating nearly 300 miles of track, of which 75 per cent. are operated by electricity.

Figs. 316 to 318 give plan, longitudinal and cross sections of the Cass Avenue Station, and Fig. 319 is an outside view of it. Fig. 320 is a plan of the whole property, and shows the general dispositions of the power house and car shed.

The Company runs 70 motor and 70 trailer cars, and in 1893 carried

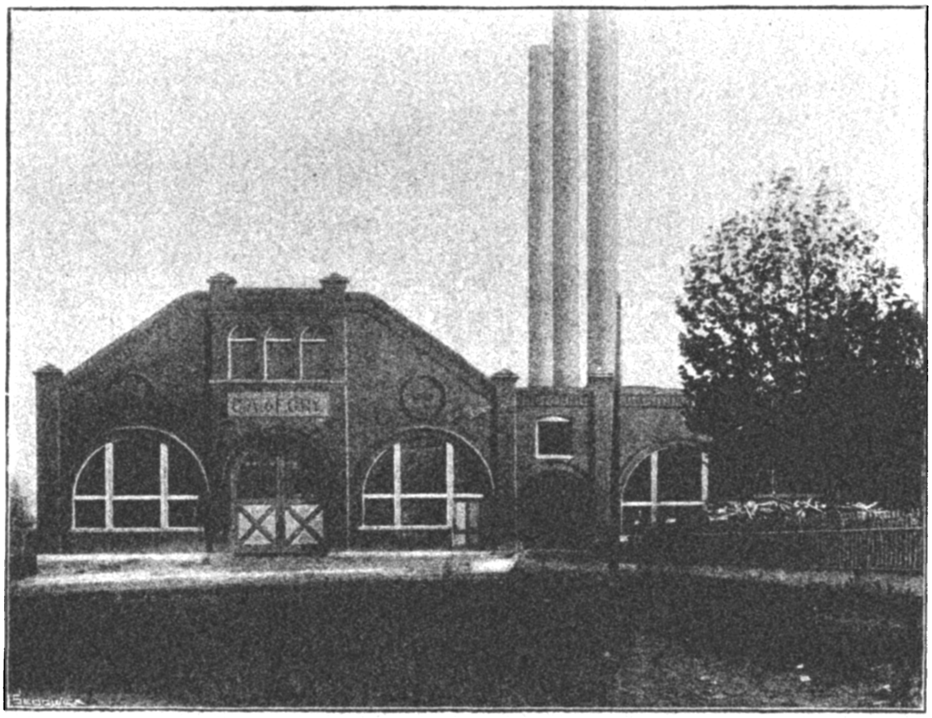


FIG. 319. FRONT VIEW OF CASS AVENUE POWER HOUSE, ST. LOUIS.

$7\frac{1}{2}$ million passengers. The capital of the company is 2,500,000 dols. in shares and 1,800,000 dols. in debentures.

The track construction adopted is exceedingly heavy, consisting of from 85 lb. to 100 lb. girder rails, laid on wooden cross-sleepers 2 ft. 6 in. apart. This company was one of the first to try electric welding of the rails, a process which has already been described in these pages.

The power station is built of St. Louis pressed brick and red sandstone trimmings. Its frontage on Prairie Avenue is 168 ft., and its depth 164 ft. The engine-room measures 164 ft. by 58 ft., and the boiler-room

164 ft. by 50 ft., the two being separated by a roadway 8 ft. wide, running the entire depth of the building, and covered in by a half-storey connecting the engine and boiler-rooms, which is used for storage purposes. The engine equipment consists of four Reynolds-Corliss engines, three of which are of 1,000 indicated horse-power, and one of 350 indicated horse-power. The three larger ones are direct coupled to three General Electric Company 750-kilowatt, 10-pole, 100 revolution generators, the smaller to a six-pole, 200-kilowatt, 150-revolution General Electric generator. The cylinders of the larger engines measure 34 in. by 60 in., and of the smaller 18 in. by 36 in. The flywheels of the two former weigh 65 tons each. The larger engines make 92 revolutions per minute, and the smaller 150. The latter is considered the highest speed Corliss engine in the world. The larger

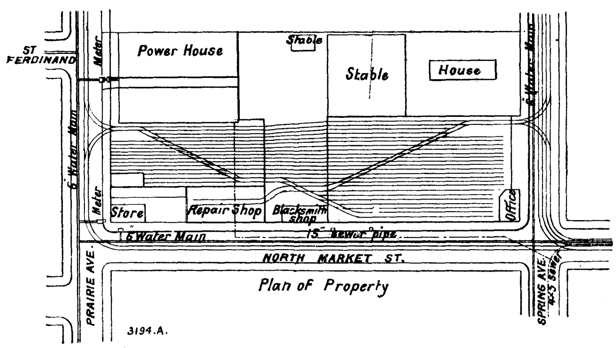


Fig. 320. Plan of Cass Avenue Installation.

engines are sometimes worked up to 1,500 horse-power, one-half more than their indicated capacity. The smaller engine and generator are used for running the all-night cars. The equipment is exactly similar in type to the 2,000 horse-power engine and 1,500-kilowatt generator used in the Intramural station at the Chicago World's Fair. The switchboard is equipped with the usual appliances, all of which were supplied by the General Electric Company.

The boiler equipment consists of six return-tubular down-draught boilers arranged in pairs. They measure 22 ft. by 66 in., and have 18 flues 6 in. in diameter. There are three sheet-steel smoke-stacks 100 ft. high. A steam pressure ranging from 75 lb. to 95 lb. to the square inch is maintained, and the water is heated in an Excelsior heater. A conveyor, running along the floor in front of the furnaces, and operated by a small upright engine, carries away the ashes and loads them on

wagons. When not in use, traps conceal the conveyor. Coal is delivered to the furnaces through doors connecting the driveway above referred to with the boiler- room. The latter is depressed about 20 ft. below the level.

The current from this plant is distributed to the line through 16 "G.E." feeder panels. The voltage is 550 volts. The cables are led from dynamos to the switchboard in concrete fireproof conduits, so placed as to be easily accessible.

Both dynamo and engine log-book are kept at the station. Two hourly readings of the electrical instruments are made one half-minute apart. The double readings are made to prevent any error, and the readings are moved forward five minutes every day, that is to say, if the first reading was taken at 5.50 one morning, readings would begin at 5.55 the next. The blanks in the log-books are for time, amperes, and volts. These records are sent to the superintendent of power stations and are transferred to books, so that a permanent record is kept. The superintendent then computes the average amperes and volts on each unit, and figures the output of each unit, in kilowatts and horse-power. The efficiency of the engines and generators is assumed to be 80 per cent. in order to obtain the "indicated horse-power" referred to above. The history of each generator and engine can be shown by the books from the time it was put in service. In calculating the total number of motor car miles, half the total trail car miles are added to the total motor car miles, and the sum is called motor car miles.

The following figures, furnished to the writer by Mr. Robert McCulloch, chief engineer of this line, may be of interest:

TABLE XC.—DATA OF FUEL AND WATER CONSUMPTION. MAY, 1894.

Average motor cars operated	70
,, trailer ,, ...	27
Daily mileage of each motor car	122 miles
,, ,, trailer car	62 miles
Average indicated horse-power at engine per car	15.86
Pounds of coal per motor car mile	8.57
,, water ,, ,, ...	46.25
Coal per horse-power hour	4.50 lb.
Water ,, ,, ...	24.22 ,,
Average daily coal consumption	977 bushels
,, ,, water ,, ...	50,530 gals.
,, ,, hours of running	24

Kent Avenue Station, Brooklyn City Railroad.—This station is one of the most conspicuous examples of direct-coupled units to be found in America. The company which owns this power station and many others was chartered in 1893, and was leased in February 1893 to the Brooklyn Heights Railroad Company for 999 years. The lessee guaranteed the company's fixed charges and a dividend of 10 per cent. per annum on its capital stock of 12,000,000 dols., the shares of which are all fully paid up. The company owns 199 miles of track, of which 174 are operated by electricity; 421 motor cars, and 109 trailer cars are run over these lines.

The special interest of this station centres in the fact that the largest direct-coupled railway generators in the world are here to be seen in successful operation. It is located at the corner of Kent and Division Avenues, Brooklyn, and occupies an irregularly-shaped plot of land about 240 ft. by 200 ft. in its largest dimensions. The foundation of the building is of granite, resting on a bed of concrete, which is supported on piling; the engine and generator foundations, of which there are six, are about 46 ft. by 40 ft., and are 24 ft. 4 in. in height, including the concrete. The bed of concrete supporting the stack is 70 ft. 6 in. square, and 6 ft. 6 in. deep, and rests upon about 1,200 piles, whose heads extend about 1 ft. into its under surface. The stonework of the foundation consist of one 2-ft. and four 3-ft. courses, all granite, a total depth of 14 ft.; the offset of the 2-ft. course is 20 in., and of the 3-ft. courses 30 in. The building itself is constructed of iron and brick, with brownstone trimmings, and the roofs are of slate and copper, resting on iron trusses; the walls are 3 ft. in thickness in the boiler-house, and 2 ft. in the engine-house, and are all strengthened by exterior and interior buttresses. The engine-room is well lighted by large windows on two sides and by a monitor roof. The boiler-house is arranged for two tiers of batteries of Babcock and Wilcox boilers; each battery consists of two boilers of 250 horse-power nominal; there are nine batteries in each tier, thus giving a nominal boiler capacity of 9,000 horse-power. The proximity of tide water allows the plant to be run condensing, and the pumping and condenser plant are installed in the boiler-house. The economisers are situated between the boiler-house and the stack. The flues in the boiler-house run along the side walls outside the boilers, and are 9 ft. by 21 ft. 6 in., and 8 ft. by 22 ft. 6 in. in largest dimensions. The stack has a 17-ft. round flue, and is about 300 ft. in height and 38 ft. $0\frac{5}{8}$ in. square at the base. The coal is taken from barges at tide water, and deposited in a coal pocket in the upper part of the boiler-house by means of mechanical

elevators and conveyors; from the pocket it is led by chutes to weighing spouts opposite the furnace doors. The ashes are conveyed by chutes opening in front of the ash-doors to the basement, where they are received in cars and carried away. This system has already been described in a previous article. The piping is all in duplicate, and, owing to the large size of the pipes and the number of component parts, is rather complicated.

The engine plant consists of six E. P. Allis Company cross-compound

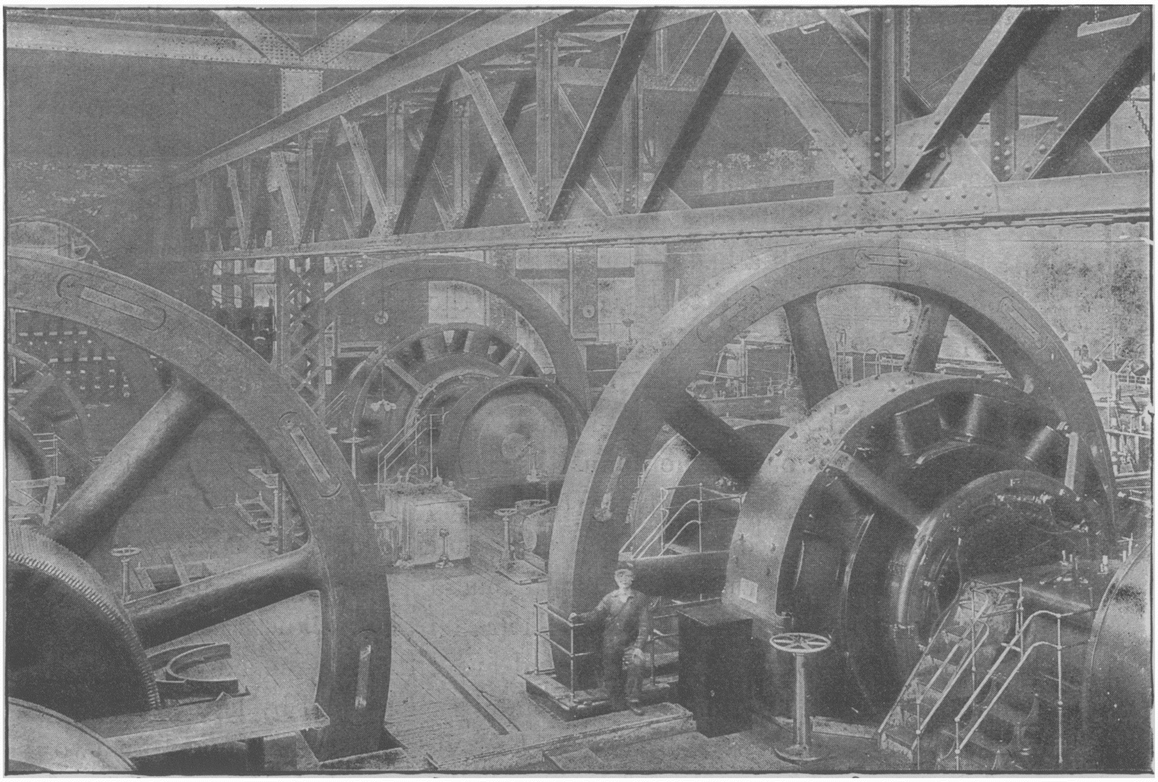


FIG. 321. KENT AVENUE POWER HOUSE, BROOKLYN.

engines, with cylinders 32 in. and 62 in. in diameter and 60 in. stroke, each rated at 2,000 horse-power. Each engine drives directly a 1,500-kilowatt multipolar generator of the twelve-pole type, built by the General Electric Company, and similar to the one which was in operation at the World's Fair. This generator has already been fully described in these articles. Fig. 322 gives a good idea of the machine, and Fig. 321 shows the inside of the station in which these machines are running. These generators have their armatures mounted directly on the engine shaft next to the flywheel,

and have a speed of 75 revolutions, giving an output of 3,000 amperes at 500 volts. The condensing plant for both stations consists of the improved Wheeler surface condensers, one condenser for each engine. The same type of condenser is also used in the West End Street Railway Company's power station at Boston, where very satisfactory results have been attained. The offices, store-room, and entrance are on the Division Avenue side, and no pains have been spared to make this one of the most complete, as it is one of the largest, power stations in the country.

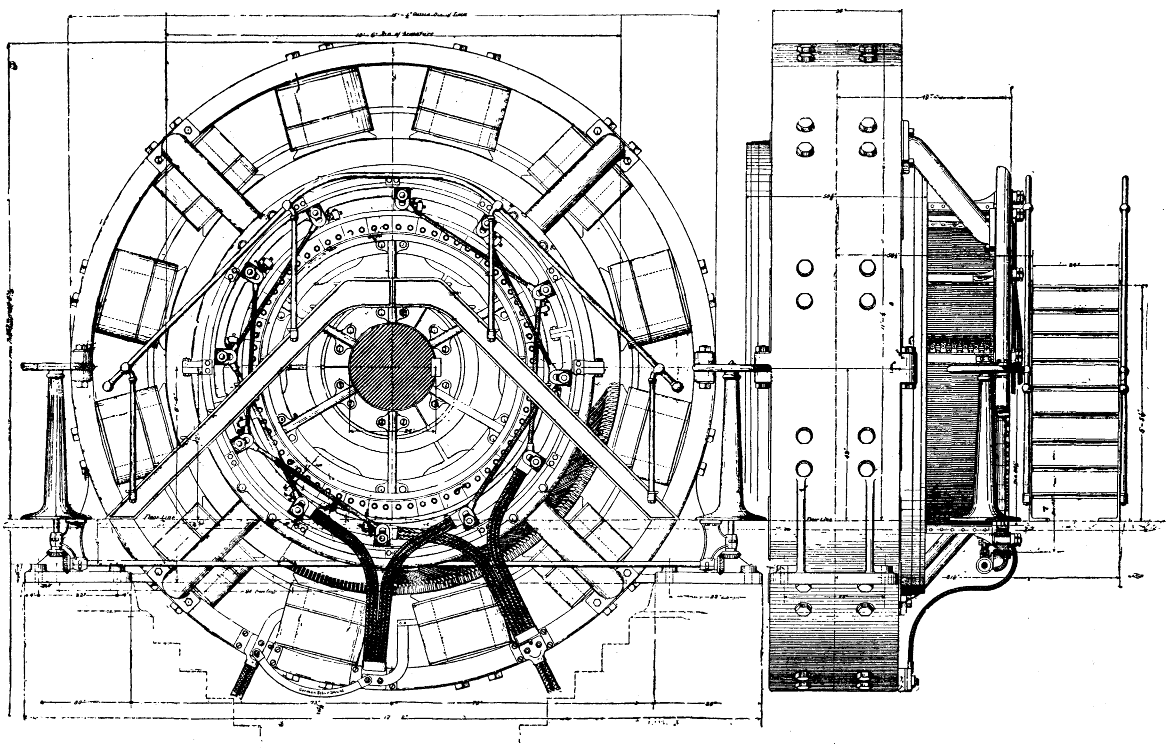


Fig. 322. 1,500 K.W. "G. E." Direct-Coupled Railway Generator.

As already mentioned, the system of live steam piping adopted is duplicate throughout. Two large mains, 20 in. at their point of largest diameter, and dropping off to 14 in. in diameter, extend the entire length of each boiler floor, and are connected to the steam drums on each boiler by headers 8 in. in diameter. Each of these mains is connected with a separator, and thence, by means of four 20-in. pipes, to four mains extending under the engine-room floor. Valves are arranged so that any boiler can feed into any main, and any portion of the mains of any boiler can be put out of connection. For operating non-condensing, each side of the engine-

room has a duplicate system of 36-in. exhaust pipes, making four pipes in all. Each duplicate set of pipes enters a 42-in. standpipe, with a Stein exhaust head 84 in. in diameter. Each engine is also fitted with a receiver, separator, and reducing valve. Lubrication is secured by a special system of piping from an oil reservoir, situated over the economiser room, to each of the bearings, whence the oil passes to a filter and is thence pumped back to the reservoir. The engine-room also contains two travelling cranes of 30 tons capacity each. If for any reason the engines should exceed their rated speed by more than 10 per cent., an automatic stop valve for that especial purpose closes and cuts off the steam. This stop valve is automatically worked by a special governor. The drip system in the engine-room is very complete, the water of condensation being returned to the boilers by means of automatic drip pumps. Water from the boiler-house pipe drips is returned to the boilers by gravitation in the usual manner. The switchboard is situated on an elevated platform at one end of the station, and overlooks it. In general appearance it resembles the one in the central power station of the West End road of Boston.

The feeder panels are on an inclined board in front of the main switch-board.

The Niagara Falls Park and River Railway.—This interesting electric road was built and equipped in 1893, and serves to connect Queenstown on Lake Ontario with Niagara Falls and Buffalo. Queenstown is connected by a regular service of fine steamers to Toronto, about forty miles away. The road follows the Canadian side of the Niagara River. The gradients met with are not severe, except near Queenstown, where a 5 per cent. grade rises from the level of the lake to the higher ground, which on each side skirts the Niagara River along this part of the course. The road follows very closely the windings of the river, giving the passengers exceedingly beautiful views of the Rapids and Whirlpool. The line is built on Government property for the greater part of its length, and the railway company pay a rental of £2,000 a year for the privilege of running their line so close to the river.

The line is about twelve miles in length, and during the past year has been double tracked throughout. The track construction resembles in every way the standard adopted by the Canadian Pacific Railway. The rails weigh 56 lb. to the yard, and rest on 8 in. by 6 in. cedar ties, spaced from 2 ft. to $2\frac{1}{2}$ ft. apart. The line is standard gauge. The track is ballasted with 18 in. of broken stone. The maximum speed attained by the electric

cars is thirty miles an hour. The poles used for suspending the trolley wires are partly wood and partly iron, wood being used along the outlaying parts of the line. The trolley wire used is No. 2/0 B. and S. hard-drawn copper wire. Most of the feeders used are carried overhead, but where the line passes through the park on the Canadian side of the Falls, the feeders have now been laid underground. There are two power-houses, the main station situated at the Falls, and worked by water power, and a smaller auxiliary plant located at the Queenstown end of the road, and which is only used when exceptionally heavy traffic has to be met. The latter power-house is a wooden frame building, and equipped with two Wheelock condensing engines, each driving a 100-kilowatt four-pole Thomson-Houston generator. The chief power station is of great interest, owing to the very successful application made of water power to traction purposes. The water is brought from the Rapids just above the Falls, by a flume 200 ft. long, to the gates, from where it is connected to two 1,000 horse-power vertical turbines running at 225 revolutions per minute under a head of 62 ft. From the wooden head-race the water is discharged into a stone forebay with iron head-gates 7 ft. in diameter. From here the water is conducted through two iron intake pipes, into two vertical penstocks 44 ft. deep and $7\frac{1}{2}$ ft. in diameter, made of $\frac{3}{8}$-in. steel plate. Five feet from the bottom, these penstocks are enlarged to $10\frac{1}{2}$ ft. in diameter, so as to receive the wheels. Draught tubes 9 ft. long are attached to the bottom plates of the wheel. The wheel pit is 85 ft. in depth, the tail water standing at about 12 ft., and is of sufficient size for three turbines, although at present but two are in operation. The wheels are 45 in. in diameter. The upright shafts are of forged steel 6 in. in diameter, and are supported by four iron bridge trees in each penstock, having lignum vitæ boxes and thrust bearings. The water, after having been utilised in the turbines, escapes through a tunnel 600 ft. long, to just below the Horseshoe Falls. The turbines are connected to a countershaft by means of mortise and cast-iron bevel driving gear. The driving gear is 75 in. in diameter, 18 in. face, and $5\frac{1}{2}$ in. pitch, and meshes into pinions $66\frac{1}{2}$ in. in diameter on the main shaft. The cast-iron gears have cut teeth, and are banded with heavy wrought-iron bands, each pair weighing about 6 tons. The main shaft is of forged steel $7\frac{1}{8}$ in. in diameter, and is furnished with friction clutches capable of transmitting 350 horse-power each. There are three 200-kilowatt four-pole generators driven by belts from the countershafting, and compounded so as to give 500 volts at no load and 600 volts at full load at 475 revolutions

per minute. These generators are connected to three standard main switchboards, and the connections between these and the feeder boards are such that the machines can be run in parallel, or separately at different voltages, so that different feeders can be fed at different voltages whenever the service on the line requires it. The foundation of the generators is solid rock.

The difficulty met with hitherto in working electric railways by water power is that it is very difficult to govern turbines so as to give a constant speed when the load varies suddenly between very large limits. Where, as in the case at Niagara, the amount of water consumed is of no consequence, a very ingenious device employed successfully on this line may be recommended. It consists in automatically keeping a constant current, no matter how many or how few cars are on the line, and using up the current not required for motive power in heating the resistances, the number of which is automatically governed according to the amount of power required by the cars. The mechanism of this device has already been fully described in a previous chapter, and need not therefore be gone into at length.

In summer the cars follow each other on this line on a 15 minutes headway, and their average speed, including stoppages, is about 13 miles an hour. The company owns 22 motor cars, each fitted with 25 horse-power motors. Some of these are open cars, 28 ft. over all, and 10 are observation cars, measuring 35 ft. and mounted on two bogies. An observation car, when fully loaded with passengers, weighs very nearly 20 tons. Besides the motor cars the company owns one private car, a baggage car, and 18 trailers. The capital of the company is £200,000. The road is operated on week-days for 15 hours, and for 12 hours on Sundays. There are eight regular stopping places along the line furnished with platforms.

CHAPTER XXII.

LONG DISTANCE POWER TRANSMISSIONS, PORTLAND, OREGON.

THE introduction of alternating currents, and especially of three-phase transmission, has enabled power situated at great distances from the centre of distribution to be made available. Where water powers are abundant and reliable, there is little reason to doubt that electricity will supplant steam as the motive power for railways. At present, alternating single or multiphase motors have not yet been sufficiently developed to adapt themselves to the necessities of traction, but it is more than probable that this will be the case in the near future, and that they will much simplify the problem of long distance railways. Power at very high tensions, say up to 20,000 volts, can then be supplied at intervals along the line, and transformed by means of stationary transformers requiring no attention to the safe running pressure of 400 or 500 volts. Thanks to the high pressure used in the feeders, these will not be expensive. Primary sources of power, say every hundred miles or so, will suffice. Nothing of the kind has yet been done, although comparatively distant water powers have been utilised in towns both for lighting and tramways. A very good example of such an installation, and one of the first, is that of Portland, Oregon.

The Portland General Electric Company, of Portland, Ore., of which Mr. P. F. Morey is president, was organised three years ago with a capital stock of 4,250,000 dols., and has purchased the entire water power of the falls of the Willamette River at Oregon City, twelve miles above the city of Portland. The minimum capacity of the river at this point is estimated to be 50,000 available horse-power under a head of 40 ft. The steppe of the falls is composed of basaltic rock, and has a very irregular outline, being very much worn by the action of the water. A dam was thrown across the river some years since, following the irregular lines, and there are numerous factories and mills in operation, to which over 4,000 horse-power of direct water-power is now leased. (Fig. 323).

One of the principal plants operated by water is an electric station, situated on a rocky island near the middle of the river, at which current is

generated and transmitted to Portland, where it is employed for lighting the streets and dwellings of the city, and also for the operation of that section of the East Side Street Railway lying between Oregon City and Milwaukee, a distance of seven miles. For the running of the lighting generators, seven vertical Victor turbines are employed, and one 500 horse-power horizontal wheel of the same type, while one 200 horse-power horizontal wheel drives the railway generators. The loss in the transmission of the lighting current to Portland, a distance of twelve miles, is stated to be only 10 per cent.

The new power station (Figs. 324 to 328) is located on the west side of the river, opposite Oregon City, and borders the canal, the front wall being a portion of the new concrete wall built for the purpose of

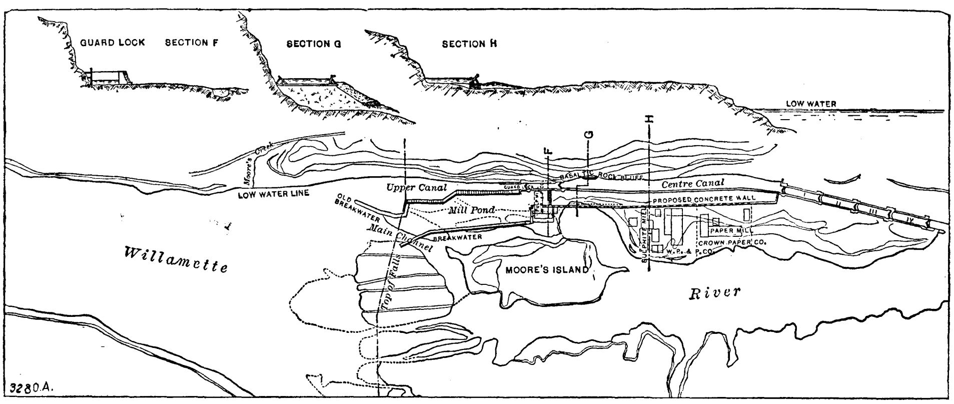


FIG. 323. WILLAMETTE RIVER AT OREGON CITY.

widening the canal, and through which the water is led to the wheels. New and substantial bulkhead gates have been installed. The ultimate capacity of the new station is to be 12,000 horse-power; only 6,000 horse-power, however, is at present installed.

The structure is of concrete, stone, iron and brick, and will ultimately be 364 ft. long; the eaves are 77 ft. above mean low-water mark, the width of the building being 38 ft. The water is taken from the canal, and after passing through the wheels is discharged into the river below. Fig. 327 presents the river side of the structure, from which it will be noted that the upper floor is lighted from transoms in the monitor roof and a row of ordinary windows, while the middle floor is lighted through circular openings in the wall, 4 ft. in diameter, furnished inside with a bull's-eye sash and glass, 3 ft. in diameter, and made to close water-tight, like the ports of

ocean steamers. These are designed to protect the interior during periods of excessive high-water. Figs. 324 and 325 are plans.

The units of power, of which there are ten, are entirely independent. The motive power is furnished by a pair of vertical cylinder gate Victor turbine wheels 42 in. and 60 in. in diameter. The large wheel is auxiliary to the other, and is provided for use only at periods of excessive high water, which, according to the records, occur usually every five years. The wheels are located on the same level, one in the rear of the other, and only about one-half the distance below the level of the water; thus the weight of the water in the discharge pipe is as thoroughly utilised as if it were all above the wheel. The lower end of the pipe is always below the surface of the

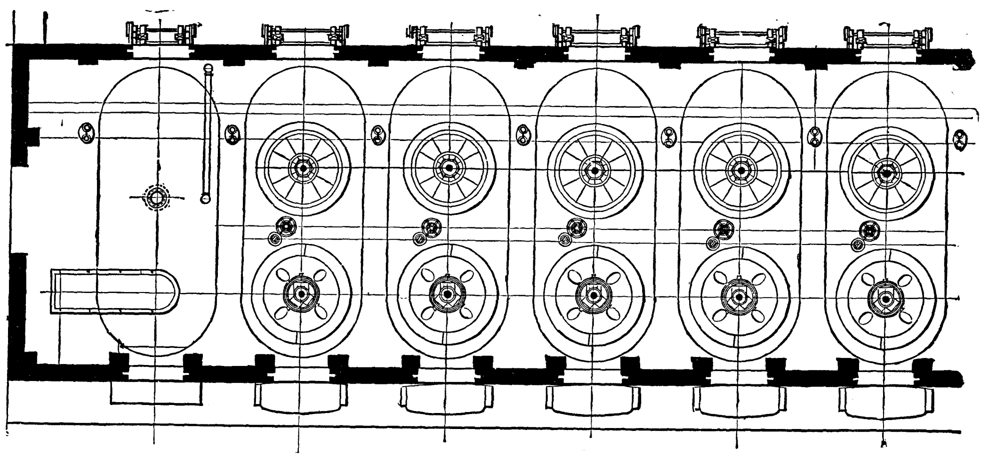


Fig. 324. Plan of Power Station, Oregon City.

water in the tail race, so that the weight tends to form a vacuum next the wheel.

The three-phase generator of each unit is of 600 horse-power capacity. wound for 6,000 volts, and is located on the upper floor of the building, with the armature in a horizontal position attached to the vertical shaft of the 42 in. wheel, and 30 ft. above it. The wheel is designed to run at a speed of 200 revolutions per minute. The shaft of the 60 in. wheel, which is only to be utilised during periods of high-water, is provided with a horizontal belt pulley, 12 ft. in diameter and 41 in. face, from which the power is transmitted by a leather belt to a 6-ft. receiving pulley on the generator shaft, both being placed 12 ft. above the wheel. This reduction causes the large wheel, which makes but 100 revolutions per minute, to drive the generator at a uniform speed of 200 revolutions, the same as the

42-in. wheel. When it becomes necessary to employ the large wheel, the generator shaft is uncoupled from its wheel at a point just above the flume, and the belt is brought into contact with the pulleys by means of a tightener pulley.

In order to support the belt in place when not in use, the pulleys are surrounded by a shelf and rack, with perpendicular pipe guards, which is also attached to the tightener pulley, and which, by the movement of the latter away from the belt, carries the belt with it, and causes it to spring away from the surface of the small pulley, so that it receives no frictional wear while idle. An interesting feature of the equipment is the types of

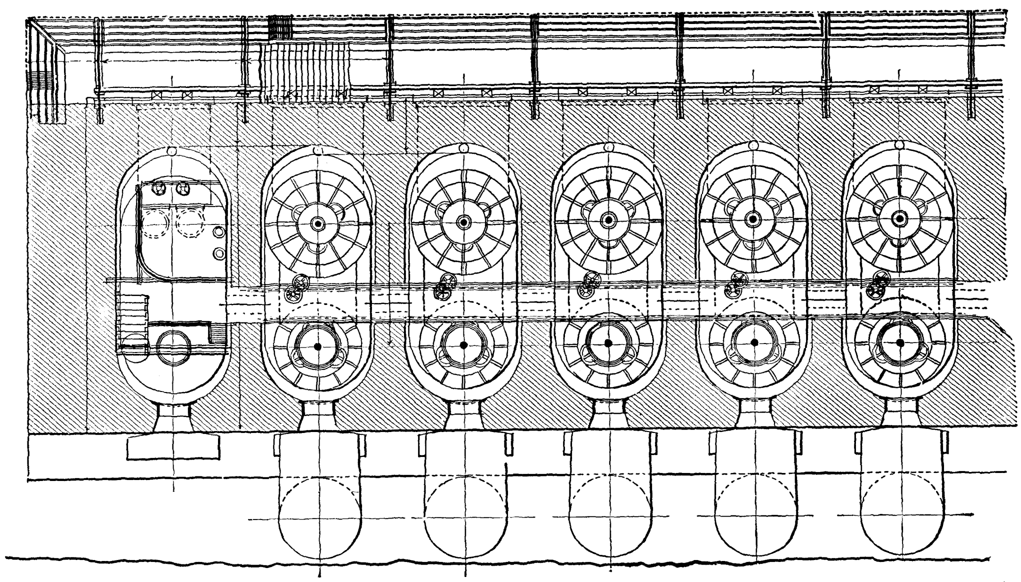


FIG. 325. PLAN OF POWER STATION, OREGON CITY.

bearings which are employed to support the weight of the vertical shafts, the armature and shaft weighing together 33,500 lb. The wheel shafts are supported on double step bearings, as is customary in vertical turbine wheels, but these not being sufficient to carry the weight of the shaft and armature, extra bearings are provided, and these are of two types—a ring thrust bearing, similar to those commonly employed on the propeller shafts of steamboats, and an hydraulic oil bearing, which supplements the ring bearing on the generator shaft. Both types are inclosed in cases, to which the oil is delivered by hydraulic pressure, and all the cases are water-jacketed for the purpose of absorbing the heat generated by friction. The ring bearings are adjustable, and are so constructed that the oil cannot fly

off or run down the shaft. The generator shaft, which is 29 ft. in length and $8\frac{3}{8}$ in. in diameter, while it is an extension of the shaft of the 42-in. wheel, does not rest upon the latter, and the faces of the disc couplings, through which the power is transmitted, are ordinarily about $\frac{1}{2}$ in. apart. The couplings are connected by twelve 2-in. vertical bolts, tapered at the lower ends, and held firmly in the lower plate by heavy nuts which simply pass through close-fitting holes in the upper plate, so that the generator shaft has a slight free movement up or down, and may be readily uncoupled from the wheel-shaft by removing the nuts and lifting out the bolts. The extension of the 60-in. wheel-shaft is 23 ft. long and $9\frac{3}{8}$ in. in diameter, and is supported by a ring thrust bearing. The hydraulic oil bearing will carry the load of the generator shaft under ordinary conditions, but it can all be transferred to the ring bearings when necessary. In the construction of the hydraulic bearing the shaft is encircled by a 4 in. ring, which has its lower face inserted in a sealed case filled with oil and kept at a constant pressure of 275 lb. per square inch. The thrust bearing cases are supported on cast-iron pedestals resting on the top of the wheel flumes. Both water-wheels are controlled by the same vertical shaft, which is provided with a handwheel on each floor, and both are regulated by the same governor. By shifting the bevelled gears on the governor mechanism, the gates of either wheel are operated by the one handwheel and governor as desired. The belt tightener is also controlled from either floor by means of a handwheel.

The water is admitted to the penstock from the race by means of head gates operated from a platform alongside of the building, each of which is provided with a small gate which is first opened, and which allows the penstock to fill, and so balance the pressure against the main gate, and permit of its being readily raised. The penstocks are each 10 ft. in diameter, and are constructed of riveted steel plates. The flumes inclosing the wheels have cast-iron heads and steel sides, and arranged so that the water passes first through the large flume and on through a short penstock to the flume of the 42-in. wheel, and from the wheels it is discharged directly into the draught tubes, which are reunited before reaching the tail-race. The draught tubes are thoroughly anchored to the step of the foundation as shown.

The intake chutes have paddle-like openings closed by means of a hollow cylinder gate fitting the openings closely all round. The turbine is mounted within the gate, which, on being raised, allows the water to pass through the chutes on all sides, when it comes in contact with the curved

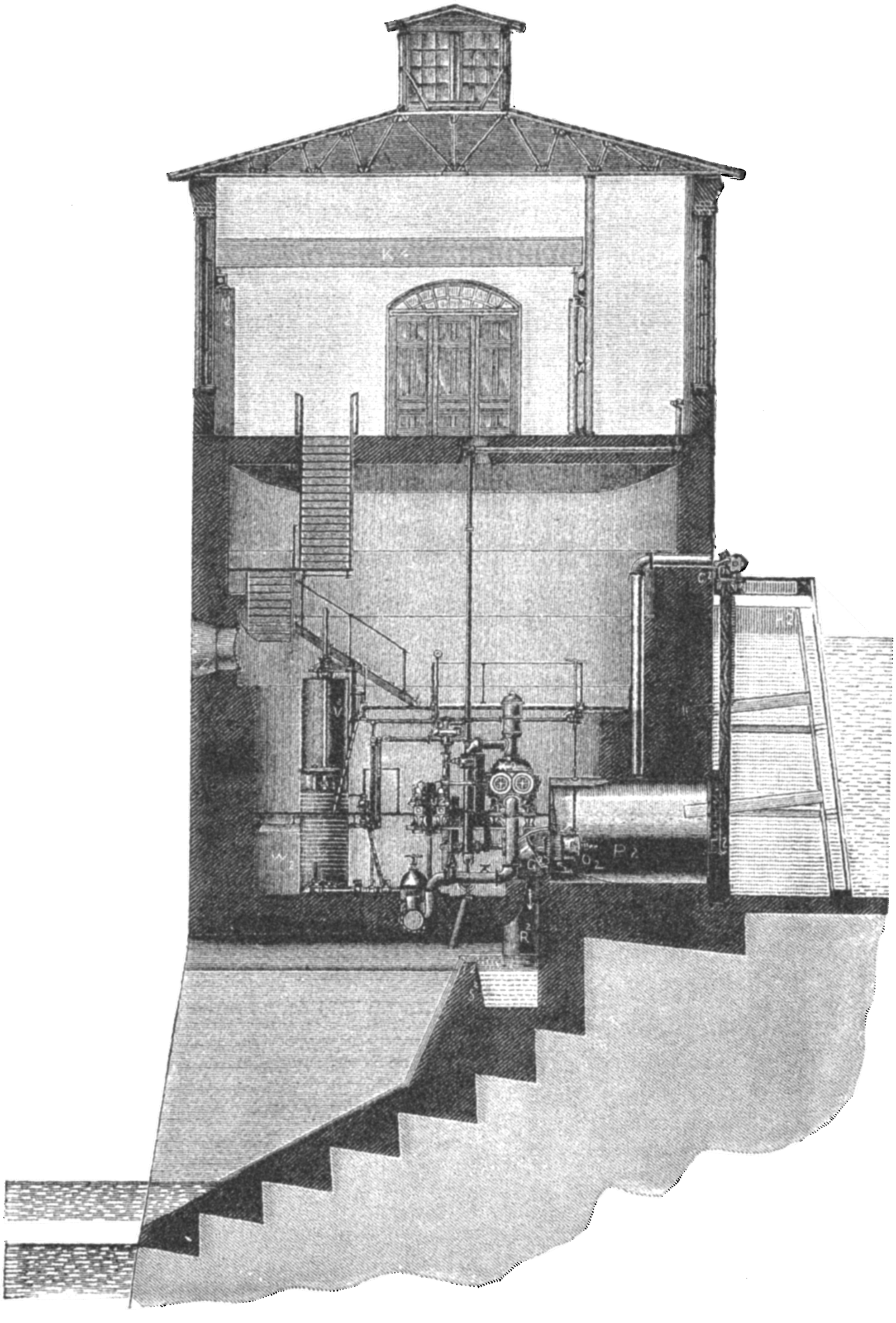


Fig. 326. Arrangement of Pump Room, Oregon City.

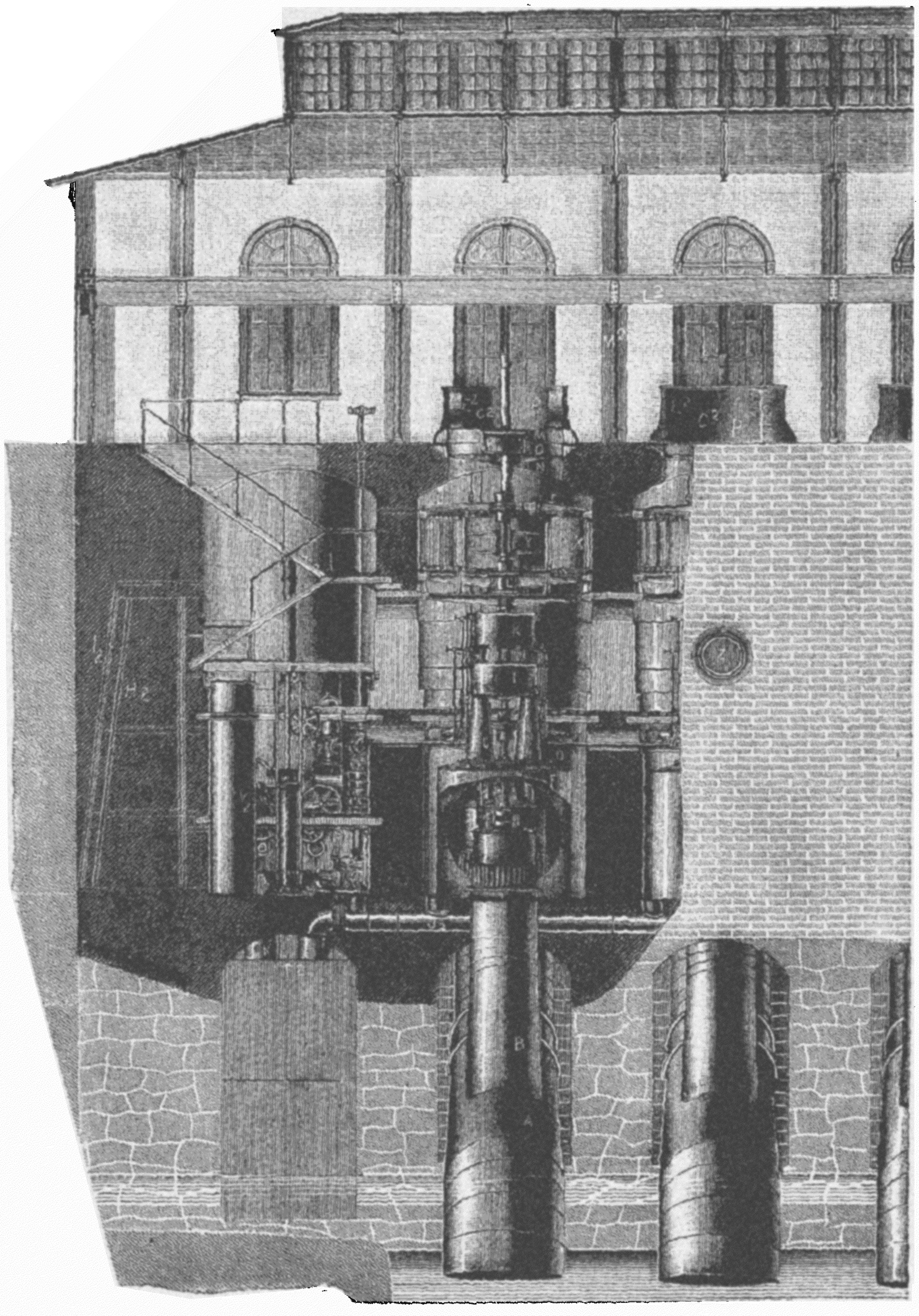


FIG. 327. LONGITUDINAL SECTION, OREGON CITY PLANT.

buckets of the wheel, and passing through is discharged at the under side of the wheel. The force of the water is applied to the wheel at two points, first by impact against the buckets, and second by the reaction of the discharge. The cylinder gate is raised or lowered by means of a wire rope and weight operating over the grooved pulley.

The auxiliary power equipment of the station consists of a set of pumps, including a hydraulic pump for supplying oil to the thrust bearing cylinders, and a duplex water pump for keeping up the circulation in the water jackets about these cylinders. The pump-room occupies the first or left-hand section of the building, and the pumps are operated by means of two 15-in. horizontal Victor turbines, inclosed in the same flume, one of which operates the duplex power pump for supplying the cylinder jackets, and the other the hydraulic oil pump.

The oil is first delivered to an accumulator, the plunger of which is weighted so that the pressure is kept uniformly at 275 lb. to the square inch. The arm of the accumulator is connected with a governing mechanism, and automatically regulates the supply of oil in the cylinder. The pipes connecting the pump with the accumulator are provided with check valves, so that in case there should be a break in the pipes at any point, the pressure would not be reduced in the supply pipes or cylinders. Another chamber which occupies the centre portion of the building is provided with a pair of vertical turbine wheels and generators. The wheels are each 48 in. in diameter, and operate a pair of exciters of 400 horse-power capacity at 125 revolutions per minute, each of the armatures of the exciters being attached to the vertical shafts of the turbines in the same manner as described for the generator armatures, both shafts being provided with ring and hydraulic thrust bearings. In this case the shafts are not belted together as in the generator-room. The turbines are controlled by handwheels from both floors. One exciter is usually sufficient to energise the fields of all the generators, but two are provided in case one is shut down from any cause. The ultimate electrical capacity of the station will be 12,800 horse-power divided into 22 units.

An electrical overhead travelling crane of 12 tons capacity is provided in the generator-room for the purpose of handling armatures and other heavy parts. This crane has a longitudinal movement of about 360 ft., and a cross movement of 24 ft. 6 in. The switchboard is located near the centre of the station and supported against the columns which carry the crane.

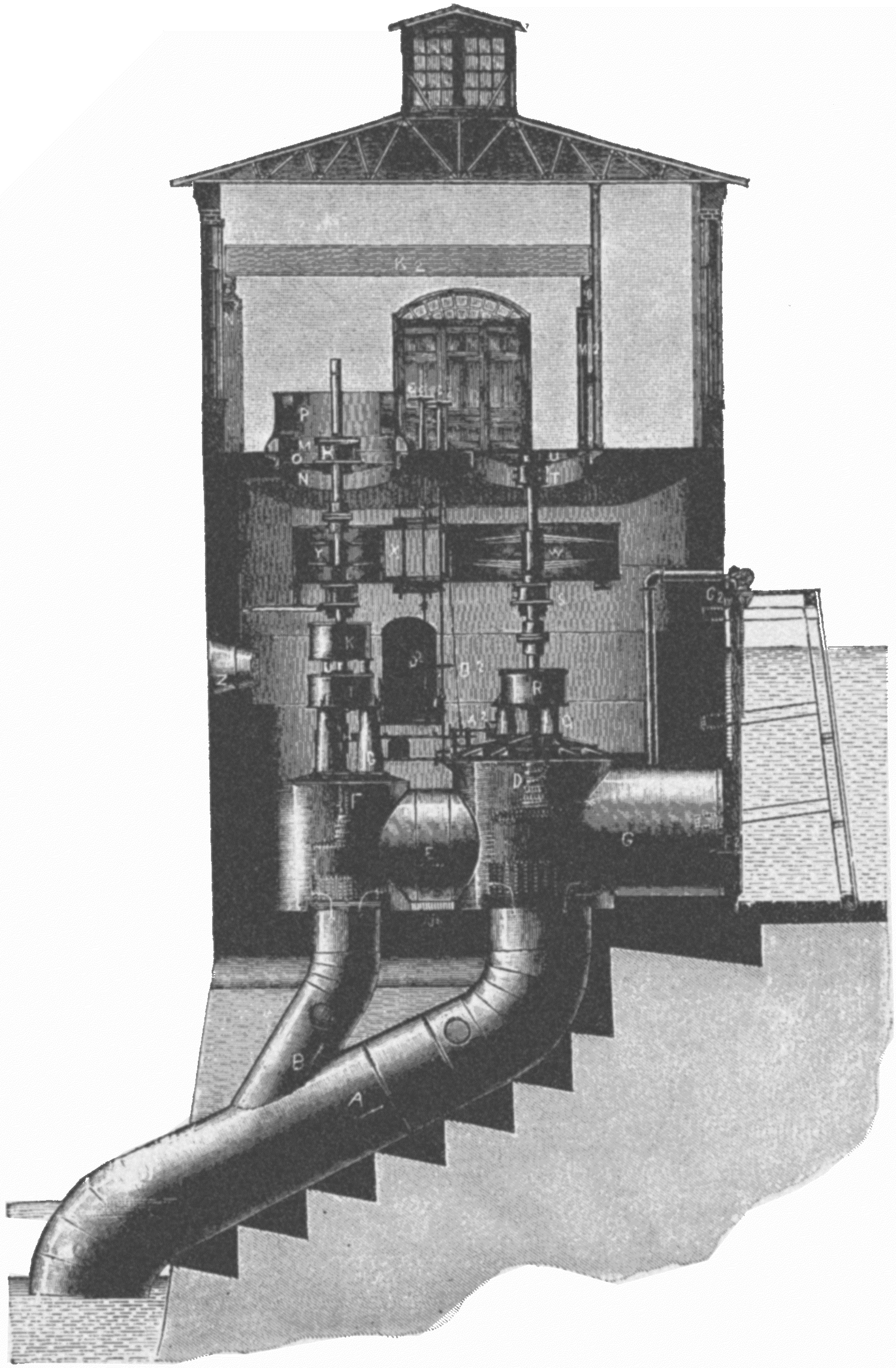


Fig. 328. Transverse Section, Oregon City Plant.

Fig. 323 shows the location of this station and the industrial plants now in operation. The various figures give different views of the power station, one of them showing to the left the interior of the pump-room, one of the lower units, and a portion of the second unit, a cross-section showing a pair of wheels and the generator, from a position looking up stream. In these figures A and B are the draught tubes, C and E the penstocks, D and F the flumes inclosing the wheels, which are shown by the dotted lines; G and Q the pedestals supporting the bearing cylinders, K the hydraulic cylinder, W the 12-ft. transmission pulley, Y the 6-ft. receiving pulley on the generator shaft, X the belt tightener. P is the generator, C_2 and B_2 the handwheels for controlling the gates; E_2 and D_2 the wheels for controlling the belt tightener pulley, and A_2 the governing mechanism.

Fig. 326 shows the arrangement of the pump-room, in which P_2 is the penstock, and O_2 the two 15-in. wheels which operate the pumps from which the water is discharged through the draught pipes R_2 to the well S_2, from which it overflows and passes to the river below. X_2 is the duplex water-pump, and U_2 the hydraulic oil-pump, from which the oil is delivered to the accumulator V_2.

Fig. 327 is a section showing the pair of 48-in. wheels and the two exciters, from a position looking up-stream. Corresponding parts are lettered the same as in the other figures. Each shaft is supported by both a ring and a hydraulic bearing. L_2 and N_2 are the tracks which support the travelling crane, Z is the bull's-eye through which light is admitted to the lower room, and G_2 indicates one of the race gates. There is a drain pipe extending the whole length of the building which removes the seepage water, should any penetrate the walls during periods of high water. The entire power equipment of the station was manufactured by the Stilwell-Bierce and Smith-Maile Company, of Dayton, O. The electrical equipment is of the General Electric Company's manufacture; the generators are the largest constructed in which the armature revolves in a horizontal position, the Niagara plant excepted. Each generator weighs 64,000 lb., of which 22,000 lb. is in the armature.

When fully in operation sufficient power will be delivered to operate all the street cars of the city, light and warm the houses, and supply power to most of the manufacturing establishments and hotels. The first station of the Portland General Electric Company was erected in 1889, and is located on the east bank of the river Willamette. This station at the

present time furnishes the power for running the electric lighting system of Portland.

There are in use in Portland 1,000 arc lights and 15,000 incandescent lights. Power for operating the East Side Electric Railway between Milwaukee and Oregon City is also supplied by this station.

For the incandescent lighting system of Portland both Thomson-Houston and Westinghouse machines are used. The capacity of each of the dynamos is 1,500 16 candle-power lights. The conductors used are No. 4 B. and S. gauge weather-proof wire. The arc-light machines are 100 light capacity each.

All the incandescent and arc circuits run into a distributing station in Portland. From this point the general distribution of all the lighting, both arc and incandescent, throughout the city is handled and regulated. Rotary transformers of 500 horse-power each, and each weighing 25 tons, are located in the Portland station, and transform the alternating current into direct current for lighting and railway use.

CHAPTER XXIII.

ELECTRIC RAILWAY LOCOMOTIVES.

IN this chapter we propose to deal with the electric railway locomotive (as distinguished from the motor car), constructed with a view to train haulage, not for the purpose of itself carrying passengers or freight.

A primary objection to the electric locomotive when contrasted with the motor car lies in the unprofitable deadweight of the former, and the consequent sacrifice of that comparative lightness and compactness, which enables powerful driving apparatus to be attached under the framework of a car without trespassing upon space which can be advantageously utilised for passengers or goods.

It is apparent that, as a rule, it is preferable to employ motor cars hauling trailers than to use special locomotives, but there naturally are exceptions. Where, as in mines, a large number of small trucks must be handled, it is evident that the electric locomotive is in its proper place. The advantages offered by electric haulage for mine work are very great. The first cost may be higher, in comparison with rope haulage, but the expense of maintenance, repairs, depreciation, &c., will turn the scale in favour of electricity. Locomotive haulage is more flexible than rope haulage, and can easily be extended or changed. It is particularly well adapted for low entries, and the locomotive can be built with little or no overhang outside the rails. The electric locomotive is compact and simple in its operation, so that skilled labour is not needed. It is part of a complete system, in which one central generating station supplies power, in the form of electricity, for all mining work. The same wires which supply current for the locomotive may be utilised to furnish power for pumping, hoisting, drilling, ventilating, &c. The necessity for a separate and expensive plant for each of these uses is removed by the combination of all in one.

Electric locomotives are in successful operation at the Union Pacific Coal Company's mines at Rock Springs, Wyoming. The power station is

situated about a mile from the mouth of the mine, and contains an 80 horse-power dynamo, driven by a steam engine. Current is delivered at a pressure of 550 volts, which allows for a drop of 10 per cent. between the power-house and the mine. About 30 ft. from the mouth of the mine is placed a circuit breaker, by means of which the current may be cut off from the mine when the locomotive is employed for switching purposes outside. The locomotive used is 60 horse-power capacity, and is generally run at a speed of 8 miles an hour. The cars used are of the ordinary coal mine type, weighing each, when filled, about 3,000 lb.; when empty, about 1,000 lb. By the aid of this locomotive 30 cars were run from the loading point to the end of the track, a distance of about 6,000 ft., there dumped, and returned to the mine in 20 minutes. On another occasion the locomotive drew after it 30 loaded cars, and pushed ahead 16 others from end to end of the road without difficulty.

A 30-ton locomotive was exhibited at the Chicago World's Fair, and at that time was the largest electric locomotive in existence. It was designed for a normal speed of 33 miles an hour. Its dimensions are 16 ft. 6 in. length over all, and 11 ft. 6 in. height. The drawbar is 2 ft. 6in. above the rail. The drawbar pull was calculated to 6,000 lb. It was equipped with two single reduction motors. The speed control was effected by a series parallel controller inside the cab. The locomotive was furnished with air brakes supplied with compressed air, by a special electrical air compressor.

As an example of the difference existing in ordinary service between the locomotive and the motor car, let us compare the weights of a tramway engine and train of three cars, such as is largely used on the Continent, with a motor car. Such an engine, ready for running, would weigh approximately 14 tons (probably more, as engines weighing up to 27 tons are often used on such roads). The weight of each car, including 36 passengers, would be about 6.0 tons, the empty carriages weighing about 3.5 tons. We would, therefore, have a total deadweight of train of 24.5 tons. The paying weight of passengers would only be 7.5 tons. The ratio of useful to dead weight would be

$$\frac{7.5}{24.5}=0.306.$$

In the case of electric traction by motor cars we could assume a deadweight of 5.5 tons for the motor car, with a live load of 2.5 tons of passengers.

Taking the ratio between useful and dead load as before, we have

$$\frac{2.5}{5.5} = 0.455,$$

or about 50 per cent. greater than in the previous case.

In the case of the locomotive we can count only on the adhesion of 14 tons, supposing that the wheels are coupled to haul a load of 32 tons. In the case of the electric motor we have the advantage of the total weight to be hauled for adhesion.

Judging from recent installations, it would seem that for rapid transit, either urban or suburban, locomotives are not advisable. We may cite as examples the Liverpool Overhead Railway, the Chicago Elevated, the Nantasket Beach, &c.

The City and South London Electric Railway, it may also be noted, is about to experiment with motor cars hauling trailers.

Before the present perfection in design of railway motors had been reached, and when the question of transmission had not yet been settled, electric locomotives were used to some extent, principally because it was found too difficult to compress the cumbrous and primitive apparatus then obtainable under the body of a car. One of the first of these locomotives was operated by Siemens and Halske at the Paris Exhibition of 1878. In 1883 Field and Edison exhibited an electric locomotive named the "Judge" at the Chicago Railway Exposition.

In 1885 Daft built a fairly powerful and successful locomotive, which was tried by him on the Manhattan Elevated Road at New York.

In 1889 Sprague conducted experiments with an electric locomotive on the Manhattan Elevated, but without great success, and relinquished the problem to take up electric street-railway work.

The failure of electric locomotives at the time may be largely attributed to limitation of available funds for experimentation, immaturity of motor design, and the great difficulty of carrying on tests without interfering with existing heavy passenger traffic. The pre-eminent demands upon inventors and capitalists for a solution of distinctively street-railway questions, and the rush of business following upon success in that branch of work, prevented any great attention being paid to the locomotive until a comparatively recent period.

Where, after due consideration of prevailing conditions, the conclusion has been reached that electric locomotives are to be employed, the most important question is whether the motors shall drive direct or by means of

gearing. This depends on the track over which the machine must run, the speed required, and the power the motors are to develop. In street-railway work practice has demonstrated the superiority of gearing, but this does not necessarily follow where locomotives are considered.

The City and South London Electric Railway first used electric locomotives on a large scale, and in this case the designers adopted direct-connected motors, the armature being directly wound on the axles. Unless the track is practically smooth, this exposes the winding to excessive vibration and consequent depreciation, while to change an armature the axle and wheels must be changed as well.

The City and South London line and equipment is fully described hereinafter.

The most recent and important electric locomotives are those lately constructed by the General Electric Company of America for the Baltimore and Ohio Railway, to haul trains through the tunnel under the city of Baltimore. Three of these are now at work very successfully. The tunnel through which these locomotives pull the trains runs under the city of Baltimore, and was constructed for the purpose of giving to the Baltimore and Ohio Railroad a clear route through to the north. Previous to its construction, all trains on this railroad going north were ferried across the harbour from Locust Point to Canton. The saving of time effected by the service through the tunnel will allow the railroad to compete with the Pennsylvania or Union lines on equal terms.

The delay which this water transfer entailed acted for many years to the great disadvantage of the company, as other lines had a clear all-rail route through the city. To do away with this delay, the Baltimore and Ohio Railroad secured legislative permission to construct a tunnel under the city, and in September, 1890, work was begun upon the tunnel and line, which now runs north from Camden Station, in the heart of the city, and then east to Bay View Junction, a distance of 7.2 miles.

To complete this road the Belt Line Company was formed, and the actual construction of the tunnel and line was carried out by the Maryland Construction Company, which was formed for that purpose. The tunnel is one of the longest soft earth tunnels ever driven, and runs through the centre of the city, immediately under Howard Street, one of Baltimore's principal thoroughfares. It was built with almost no interruption to the incessant car and wagon traffic upon the surface of the street, and to secure this

result several shafts to the tunnel below were sunk through the cellars of houses. The soil through which the tunnel is driven is chiefly sand, through which run seams of gravel and a hard species of clay, which in some cases had to be blasted out. Considerable water was encountered, and to facilitate the work, the ground was drained in advance of the headings by means of wells, sunk at various points along the line of the tunnel. The length of the tunnel is 7,339 ft., and the maximum dimensions, after lining, are 27 ft. wide by 22 ft. high. Its cost, ready for the track, is set down at £45 a lineal foot. The question of locomotion made it inadvisable to employ

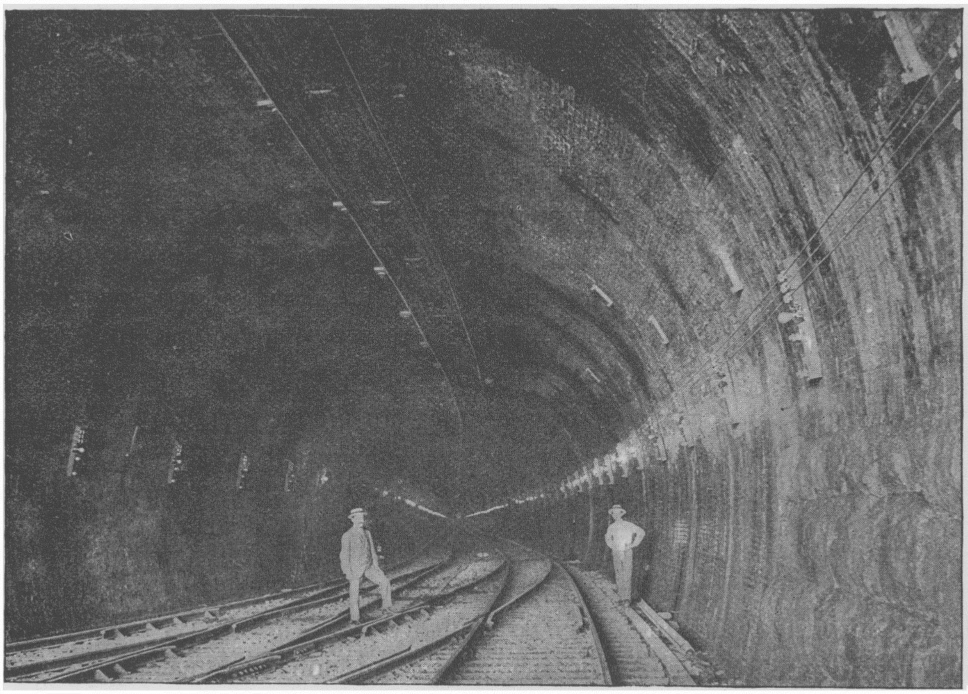


FIG. 329. INTERIOR OF BALTIMORE TUNNEL.

steam locomotives if any other efficient means could be obtained. (See Figs. 329 and 330.)

Cable traction was suggested, but rejected as inadequate. The General Electric Company of America offered to undertake the construction of electric locomotives of capacity sufficient to haul the heaviest trains, effect the entire equipment of the system, both for lighting and power, and thus to solve the ventilation problem.

The electrical equipment and the work at first outlined was as follows: The locomotives were to operate from about 1,800 ft. in the open to the

portal of the tunnel, through it, and for 4,600 ft. further on in the open, or a total distance of about 14,500 ft. The locomotives were to join the rear

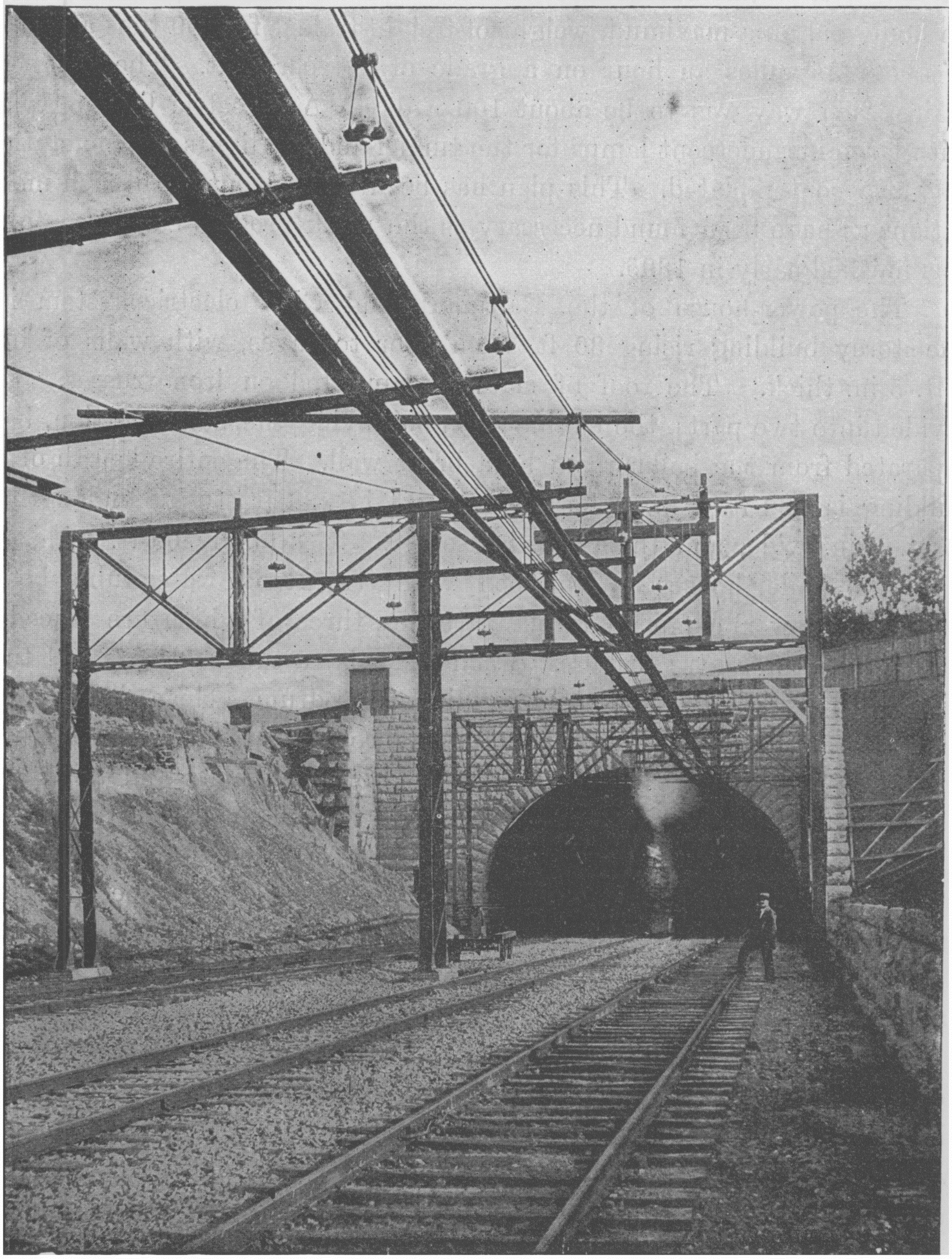


FIG. 330. ELECTRIC CONDUCTORS AT PORTAL OF THE BALTIMORE TUNNEL

end of passenger trains, and push both cars and locomotives through to the end of the tunnel, from which point the steam locomotive was to do

all the hauling. Freight trains were to be pushed the entire distance. The calculations were based on a maximum weight of 500 tons for each passenger train, including the steam locomotive, with a speed of 35 miles an hour, and on a maximum weight of freight trains of 1,200 tons at a speed of about 15 miles an hour on a grade of 0.8 per cent. The number of trains each way was to be about 100 a day. An electric lighting plant, with large incandescent lamps for the tunnel and arc lights for the stations, was also contemplated. This plan has been carried out with such modifications as have been found necessary as the work progressed. The tunnel was finished early in 1895.

The power-house of the Baltimore and Ohio electric system is a one-storey building rising 30 ft. from floor to eaves, with walls of brick 1 ft. 5 in. thick. The roof of slate is supported on iron trusses. It is divided into two parts, the engine-room occupying the north portion, being separated from the boiler-room by a brick wall. The entire length of the building is 322 ft. 1 in.; the engine-room is 223 ft. 10 in. in length by 57 ft. 9 in. wide, and the boiler-house is 98 ft. 3 in. by 69 ft. wide.

The boiler-house is equipped with 12 Root water-tube boilers (250 horse-power) arranged in six batteries, three of which are placed on each side of the centre passage. Each boiler is 12 tubes wide and 11 tubes high, with six $14\frac{1}{2}$-in. drums and a 30-in. steam drum. Space is left for an additional boiler on the west side of the room. Mechanical draught is employed, and the flues run over the rear of the boilers and taper from 2 ft. 9 in. square at the end to 5 ft. square at the junction with the fan chamber, 9 ft. in diameter, in which two fans of the Sturtevant pressure pattern revolve at 240 revolutions per minute. This chamber is at the base of an iron stack, 7 ft. in diameter and 51 ft. high from the floor. Each fan is belt driven by a 10 horse-power vertical engine, and one is of sufficient capacity to secure the necessary draught.

The boiler-room is equipped with a C. W. Hunt coal crusher and conveyor, bringing the coal to the boiler and taking away the ashes from the ashpits. Deane duplex feed-water pumps and a 3,000 horse-power Webster feed-water heater are employed. The steam pipes are duplicated throughout. The pipes are wrought iron, with cast-iron flange and fittings and ground joints. The mains from the boilers are placed high enough to allow the water to drop into the separators, from which drips return all water back into the boilers by gravity. Each main is provided with a 48-in. separator. Angle check and stop valves are used, which shut off

automatically from the system any boiler in which a tube has given way, or any part of which has met with accident.

A 24-in. separator is furnished to each power engine, and one of similar size for each pair of lighting engines. The Holly drip system is used in the engine-room, and is connected with the separators at the engines, the valves and expansion joints, wherever there is the slightest pocket in which water could lodge, returning it to the boilers. The expansion in the long steam mains in the engine-room is provided for by the use of Pearson expansion joints perfectly balanced, so that no strain is brought upon the anchorages beyond that caused by the slight friction of the plunger in the stuffing-boxes. The steam piping is lagged with magnesia covering.

The engine-room is divided into two sections, one containing power plant, the other occupied by the lighting generators. In the power section space has been provided for five direct-connected engines and generators, of which four are now in place. The engines are horizontal tandem compound Reynolds-Corliss machines, and have 24 in. and 40 in. by 42 in. cylinders. Directly coupled to them are 500-kilowatt General Electric multipolar generators, running at 110 revolutions per minute. The armatures of these generators are "overhung" on the outer end of the shaft, an arrangement differing from the regular practice of railway generators. The armatures are wound for 700 volts potential. The windings are imbedded in slots cut into the outer periphery of the laminated armature body. The armatures are drum-wound. The fields are of steel. The machine compounds from 600 volts and no load, to 700 volts with full load.

From the railway generators cables convey the current to a switchboard of white marble, erected on a platform raised at the south end of the engine-room. This switchboard consists of four standard "K" generator panels, described in previous chapters.

The lighting plant consists of eight 50-light Thomson-Houston arc generators and two alternators for the incandescent lamp service in the tunnel. Each alternator has a capacity of 2,000 sixteen candle-power lamps, and one alternator will suffice for the present illuminating of the tunnel, of which a description was given on a previous page. From the positive bus on the railway switchboard eight stranded copper cables pass to the overhead structure immediately outside the power-house, where connection is made to three feeder cables, and to the overhead conductor itself. The negative bus is similarly connected to the rails, which are

double-bonded with 4/0 "Chicago" rail bonds, and also to the return cables laid in a wooden box between the tracks. Perfect contact between bonds and web is obtained. The distance over which the electrical locomotives will operate is about 15,000 ft., passing through two tunnels 7,339 ft. and 265 ft. long respectively, and over 7,396 ft. of track in the open. There is a steady grade of 0.8 per cent. from the southern through to the northern portion, and the lines in the open have two equated curves of 10 deg., with a steady gradient of $1\frac{1}{2}$ per cent. At the power-house end of the line the locomotives run on a siding at the beginning of the long open cut running down to the southern portal.

The plan of pushing the passenger trains through the tunnel has been abandoned, in view of the possible results if one of the cars or the steam locomotive should leave the track, in front of the heavy electric locomotive travelling at thirty miles an hour. The passenger trains will be pulled through from the Lombard Street station near the south end of the tunnel to the Bolton Street station at the north end. Goods trains will be pushed through the tunnel at fifteen miles an hour, and in the open cuttings the electric locomotives will push and the steam engines haul. Table XCI. gives the most interesting data of the electric locomotives.

TABLE XCI.—Giving Data of B. and O. Electric Locomotives.

Number of trucks...	2
,, motors	4; 2 to each truck
Weight on driving wheels	192,000 lb. (96 tons)
Number of ,,	8
Drawbar pull	42,000 lb.
Starting drawbar pull	60,000 ,,
Gauge	4 ft. $8\frac{1}{2}$ in.
Diameter of drivers	62 in. outside of tyres
Length over all	35 ft.
Height to top of cab	14 ft. 3 in.
Wheel base of each truck	6 ft. 10 in.
Extreme width	9 ft. $6\frac{1}{4}$ in.
Diameter of sleeve bearings	13 in.

Figs. 331, 332, and 333 show a side and front view of this locomotive, and a side view of one of the four-wheel trucks on which the cab is mounted.

The driving gear consists of a cast-steel spider shrunk on and keyed to a cast-steel driving sleeve, having a tensile strength of not less than 80,000 lb. Each arm of the spider is provided with a double rubber

cushion, with a chilled cast-iron wearing cap, the cushion being forced into the arms of the spider and the cap. The eight driving wheels are of cast steel pressed and keyed to the axles, and have tyres 3 in. thick at centres

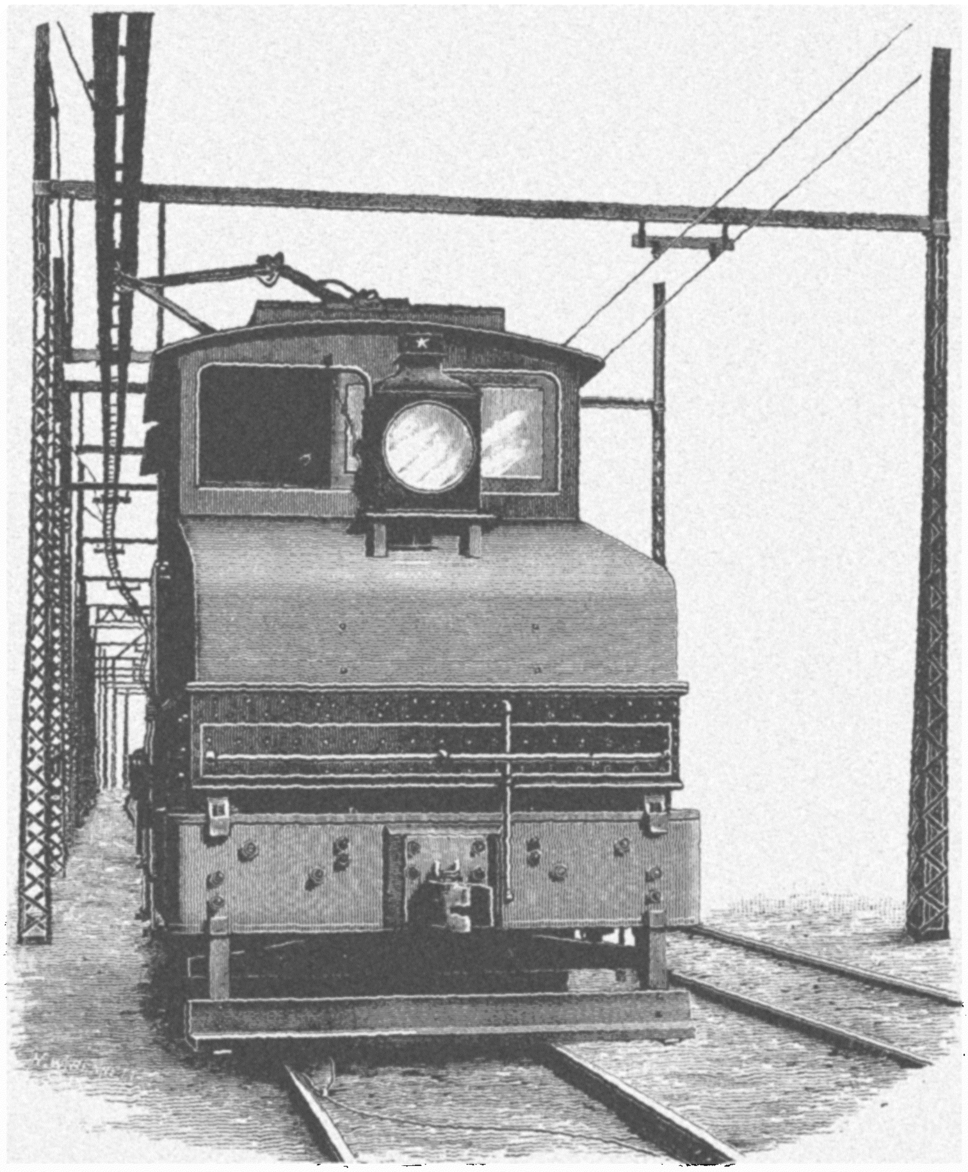


Fig. 332. Baltimore and Ohio Electric Locomotive.

of tread shrunk on to the wheel centres. The driving axles are of special open-hearth steel. The journal bearings are outside the driving wheels, and allow of easy access to all parts of the truck frame and driving box. It is of cast-iron, with a phosphor-bronze bearing fitted on in a similar manner

to that of a steam locomotive driving box. It slides in jaws protected by shoes in the same way. The box is closed at the bottom, and as a well for oil and waste, as well as a dust-guard lid. Large grease cups are cast in the journal caps, giving a satisfactory lubrication to the motor bearings.

The two opposite side frames of each truck rest upon four wheels, each consisting of one piece of hammered wrought iron, $3\frac{1}{2}$ in. thick, to which the frame jaws are welded, and protected from wear by cast-iron shoes, and are connected together at the ends by heavy forged iron plates with oak bumper beams between them.

The drawheads are of the Janney type, similar to those used on the Baltimore and Ohio passenger locomotive tenders, and are made of cast

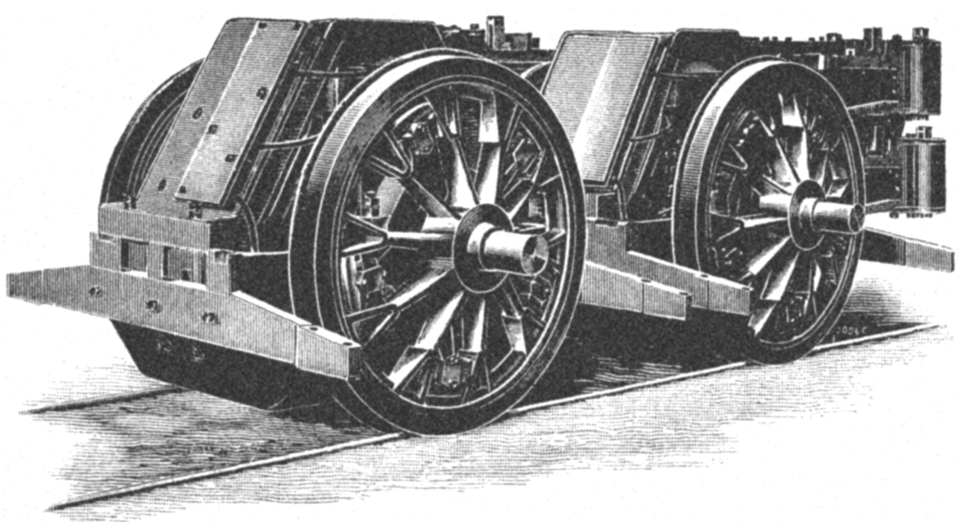


FIG. 333. DOUBLE MOTOR TRUCK OF BALTIMORE AND OHIO LOCOMOTIVE.

steel with wrought-iron knuckles. In coupling with freight trains the ordinary links and pin will suffice; but for passenger service the Janney couplers, with which each locomotive is provided, are used. The front and back of the locomotive is provided with safety chains, and in addition to the regular couplings between the trucks, safety links are used. The buffers between the motors act as spacers for, and fit between plane surfaces in the field magnets. These spacers have a complete freedom of movement which allows the field magnets to rotate when the motor is in action. These buffers and spacers are so placed as to permit the interchange and reversal of the positions of the field magnet withour requiring change in the position of the spacers.

The motors are supported on carriers bolted to the field magnets, and rest in adjustable hangers carried on half-elliptical springs placed on top of the frame and bumpers. It will be seen that the frames carry the motors by carriers and springs, this load in turn being carried by rubber blocks in a cast-iron casing.

The cab is of sheet steel. Two drop windows are provided at each end and four at each side, to give unobstructed view in all directions. The doors slide laterally on large rollers, and are placed one on each side of the cab. The cab is supported on the frame by four half-elliptical springs. The cab steps are attached to the cab only, and hand-rails are placed at each door. The shields are also of sheet steel supported on coil springs directly on the bumpers, and are adapted to receive the air tanks at the ends, and bell, whistle, and headlights on the top. Arrangements are made so that all the commutators are visible to the motor-men.

The locomotive is fitted with sand-boxes, and automatic driver and train brakes provided for all wheels, bearing upon the flanges and outside tread only. A brass signal gong 8 in. in diameter is placed in the cab, to be rung from either end of the locomotive.

The gearless motors are four in number, two to each truck, flexibly supported, and transmitting their power to the wheels through the flexible connections.

Each motor has six poles and six sets of carbon brushes, the brushes being connected to a yoke revolving through 360 deg. to facilitate accessibility to them. It is possible to remove four brushes without disabling the motor. The field spools are encased in sheet iron cases, and fitted over the pole pieces bolted to the field frame. The armatures are built of sheet iron laminations, and are series drum wound. Each insulated winding is imbedded in an insulated slot, cut into the outer surface of the armature body, and held therein by a wooden key. This armature, with the commutator, is mounted upon, and keyed to, the hollow sleeve which is carried on the journals on the truck frame. The inside diameter of the sleeve is about $2\frac{1}{2}$ in. larger than the axle. The entire motor is practically fireproof.

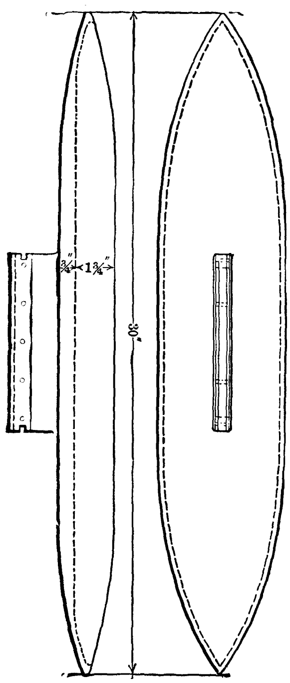
When normally placed, the motor rests in a position concentric to the axle, the clearance between the axle and the sleeve allowing of a flexible support. The interposition of the rubber cushions, through which the torque of the armature is transmitted to the driving wheels, allows the armature to run eccentric to the axle, when the motor departs from its

normal position on account of any unevenness in the track. The motor is designed to allow of ready removal of the field frame for inspection or repair.

A test of the first complete truck, representing one-half of the locomotive, was made upon the tracks at the Schenectady shops of the General Electric Company. In order to obtain the necessary load, a heavy six-wheel engine was made use of, and the electric locomotive truck coupled to it. The machines were then sent in opposite directions and pulled at the connecting coupling as in a tug-of-war. The electric locomotive had a slight advantage over the steam engine in weight on the driving wheels, and pulled it up and down the track with apparent ease. For the same weight upon the drivers it was shown that the electric locomotive starts a greater load than the steam locomotive. The pull being constant throughout the entire revolution of the wheel, the difficulty of variation of pull with the angle crank, as in the steam locomotive, is eliminated. Each motor is rated at 360 horse-power, and takes a normal current of 900 amperes. The controller is erected in one half of the cab, and is of the series parallel type. The reversing lever projects through the upper plate of the controller cover. The resistances are placed around the frame beneath the floor of the cab. The locomotive is equipped with a 1,200 to 3,500 automatic circuit-breaker, and one 2,000-ampere magnetic cut-off, a 5,000-ampere illuminated dial Weston ammeter, and one illuminated dial Weston voltmeter. The compressed air for the whistle and brakes is supplied by an oscillating cylinder electric air pump, the air tanks being placed at each end of the complete locomotive. The interior of the cab is lighted by clusters of incandescent lamps.

Contact with the overhead conductor is effected by a sliding shuttle-like shoe of brass (Figs. 334 and 335), fixed to a flexible support fastened to the top of the cab. The "trolley" support is diamond-shaped and compressible, and arranged to lean on one side or the other as the locomotive runs on one side or the other of the overhead conductor (Figs. 336 and 337). It is rigid in so far as movement forward or backward over the locomotive is concerned. The current is brought to the locomotive by cables connected to the shoe and fastened to the "trolley" support. The conductor is simply a reversed iron conduit erected overhead on trusses in the open, and in the tunnel attached to the crown of the arch (Figs. 338, 339, 340, and 341). In the open the conductor is directly over the centre of the track; in the tunnel over the centre line of the space between tracks. It

extends a distance of 15,000 ft. The conductor consists of two 3-in. iron Z-bars $\frac{3}{8}$ in. thick, riveted to a cover-plate $\frac{1}{4}$ in. thick and $11\frac{1}{2}$ in. wide, and is constructed in sections 30 ft. long. It weighs 30 lb. per foot. At intervals of 15 ft. inside the tunnel, there are suspended from the arch, transverse frames (Fig. 339), consisting of two 3-in. channels, held together by plates 4 in. wide, and holding four castings into which are fitted conical porcelain insulators. In the masonry of the tunnel are fitted the bolts necessary to support these frames. They are 2 ft. 6 in. long, have split



FIGS. 334, 335.
CONTACT SHOE, B. AND O. TUNNEL.

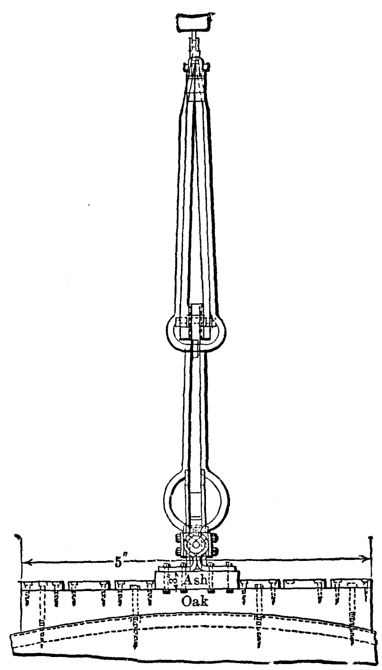


FIG. 336.
CONTACT SUPPORT, B. AND O. TUNNEL.

ends, and extend 12 in. into the masonry. The bolts pass downwards through the outside pair of insulators. The bolts attaching the conductors to the channel frames pass through the inside pair of insulators and support an iron stirrup in which the conductor hangs. This method affords a double insulation, and if leakage occur it can only be by the current passing the insulators between the conductor and the transverse channel, and then the insulation between the channel and the bolt in the tunnel arch. There may be a defective insulator either on the roof bolt or on the bolt which supports the conductor, but only when two insulators on the same transverse channel

frame are defective, will leakage occur. The height of the conductors above the level of the top of the rails is 17 ft. 6 in. in the tunnel, and they are fixed a little on each side of the centre line. This plan was adopted to avoid the risk of the conductors striking brakemen who might be standing on the top of passing freight cars. An additional precaution is provided in the shape of continuous wooden shields fastened to the iron stirrup which supports the conductors.

Outside the tunnel the height of the conductors above the rails is increased to 22 ft. The supporting structure in the open consists of two

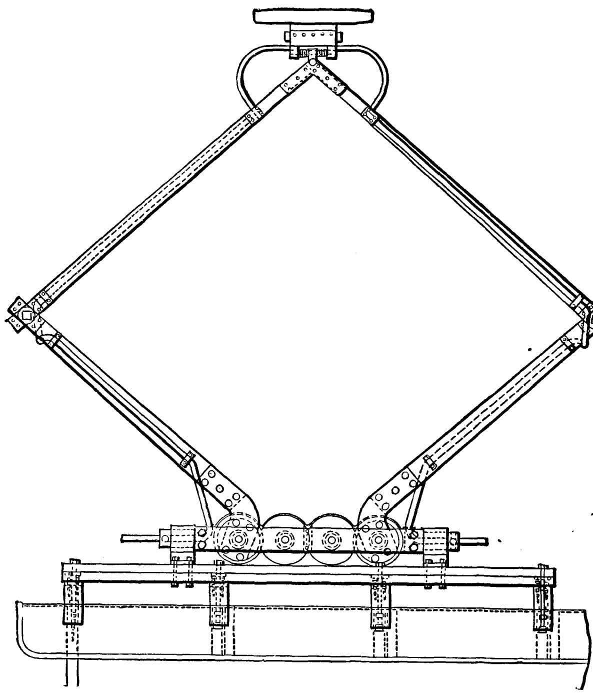


Fig. 337. Contact Support, B. and O. Tunnel.

chains of iron rods, having a span of 150 ft., suspended from transverse trusses, supported by columns of latticed steel channels erected on either side of the double track (Fig. 338). The chains pass over the top chord of the transverse trusses, and are fastened to a yellow pine timber post, acting as an insulation set therein. From the joints in the chain, rods are dropped at intervals of 15 ft. to support the electrical conductors. These rods are attached to a casting holding a porcelain insulator, and through this a short bolt passes up to the point in the chain. The double insulation is secured by this vitrefied porcelain insulator and the timber post, passing vertically

through the transverse girder. A hood of galvanised iron is fixed to the top of the timber post. At the ends of the line an anchor pier received

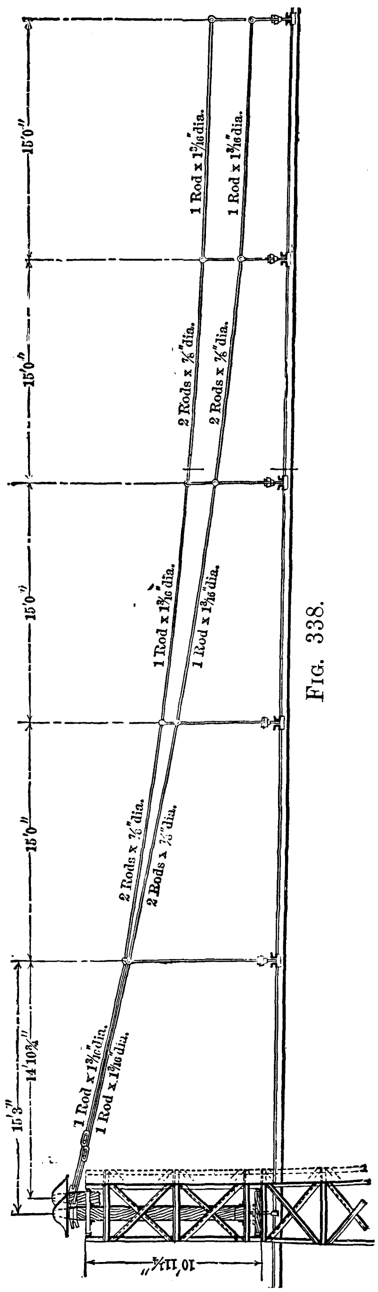


FIG. 338.

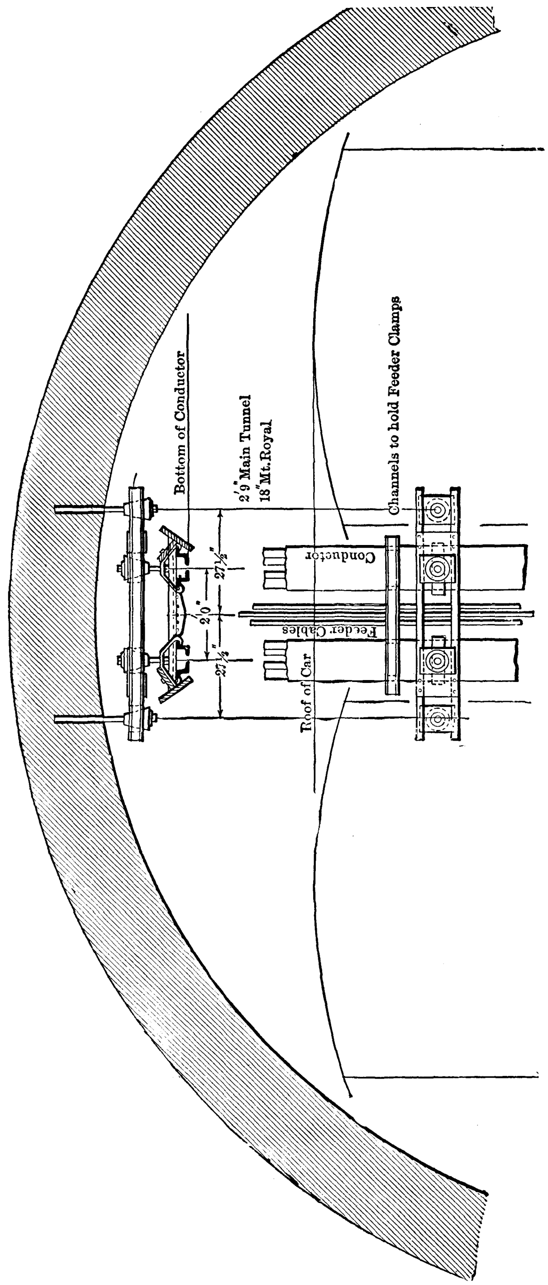


FIG. 339.

ARRANGEMENT OF ELECTRICAL CONDUCTORS, B. AND O. TUNNEL.

the ends of the conductors. The trusses vary in length from 30 ft. to 62 ft., the latter being required to span five tracks.

Upon the straight track the conductors are suspended from single chains. Upon curves a double chain is employed, and the conical insulator is inverted and supported in a casting bolted to the two vertical rods which drop from the chains. The vertical rods support a channel frame to which are bolted the conductors and the feeder cleats or clamps. Each joint of the conductor is bonded with a Chicago bond of two No. 0000 wires.

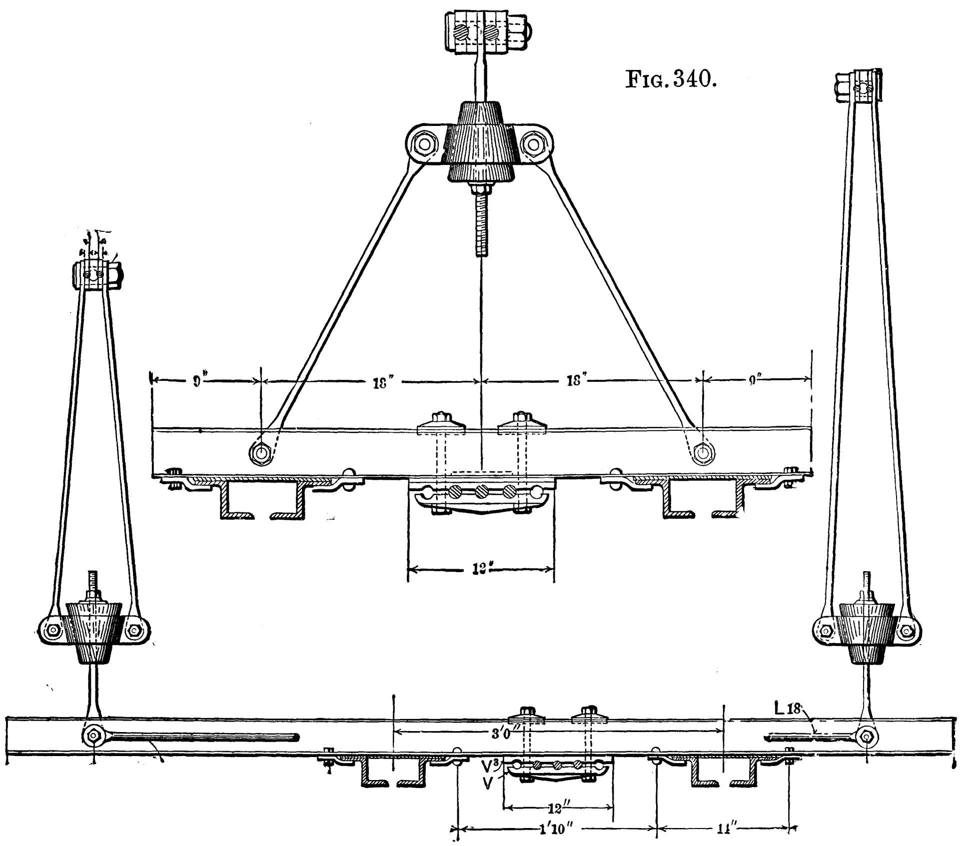


FIG. 341.

ARRANGEMENT OF ELECTRICAL CONDUCTORS, B. AND O. TUNNEL.

The feeder cables are of bare stranded copper of 61 strands; these are supported in iron cleats fastened to channel frames riveted to the overhead conductors at points near to the heavier channels to which the conductors are suspended.

The lead-covered primaries for the tunnel lighting plant are carried on posts set on the side of the cut, to the southern portal, where they drop to the tunnel and are carried upon porcelain knobs fastened to wooden blocks

bolted to the masonry. At the points of support the cables are armoured with wire to prevent abrasion. The secondaries are carried in cleats also fastened to wooden blocks, similarly attached, and placed on either side of the tunnel about 8 ft. from the ground and 15 ft. apart. They are, however, staggered, and thus occur alternately at every $7\frac{1}{2}$ ft. throughout the tunnel. Each block carries a lamp at its lower end, and is there cut out so that the lamp socket may be protected from moisture and dripping water from the tunnel walls. The lamps used are 32 candle-power, 52-volt Edison standard incandescent lamps.

At the present moment all the freight and passenger trains of the Baltimore and Ohio Railroad are being run through the tunnel by the electric locomotives.

The first locomotive supplied has been running steadily since August 4, 1895. The following are the results of recent tests that have been made with it.

A train consisting of 27 loaded freight cars, and two steam locomotives not working, of a total weight of 1,125 tons, was hauled up a gradient of 42 ft. to a mile. At the end of 1 minute the train was moving at a speed of $10\frac{1}{2}$ miles an hour, and at this point the speed was increased to the usual rate.

Another test was made with a dynamometer, placed between the electric locomotive and the train, which consisted of 22 cars loaded with coal, and one guard's brake. The total weight was 1,068 tons. In the tunnel 25,000 lb. dynamometer strain was obtained. With a speed of $11\frac{1}{8}$ miles per hour and a train 1,600 tons weight, the drawbar pull was 45,000 lb. On October 6, 1895, a train 1,800 ft. long and weighing 1,900 tons, started from rest in the tunnel; it consisted of 28 loaded cars and two locomotives, and 15 loaded cars and one locomotive. The maximum drawbar pull was 60,000 lb. at 12 miles an hour.

CHAPTER XXIV.

ELECTRIC MAIN LINE RAILWAYS: THE NANTASKET BEACH RAILWAY AND THE METROPOLITAN ELEVATED RAILWAY, CHICAGO.

THE NANTASKET BEACH ELECTRIC RAILWAY.—The first instance of electricity supplanting steam in American railway practice is the Nantasket Beach branch of the New York, New Haven, and Hartford Railroad, where the first results have proved remarkably successful. The line was almost exclusively operated by the electrically propelled trains on June 30, 1895. The Nantasket Beach Railway extends from the Old Colony House Station as far as the Pemberton Station, a little beyond Hull, at the extremity of the narrow peninsula, one side of which is known as Nantasket Beach. The length of the road is 6.91 miles, and of this there are 4.4 miles of curves in about twenty curves, the sharpest being one of 10 deg. The line is almost level, the only grade being about 34 ft. to the mile. The track is laid with 70 lb. rails and stone ballast. Each joint is bonded with 4/0 copper bonds, 7 in. long, riveted into the flange of the rail. The line traverses two trestles and one plate girder bridge, the latter located near the Stony Beach Station. Engineering difficulties were, of course, met with. Six thousand yards of rock ledge were taken out near one terminus, and between Stony Beach and the terminal station at Pemberton a heavy retaining stone wall had to be built on the shore side of the track. The height of the wall varies from 6 ft. to 21 ft., and contains 6,000 cubic yards of masonry.

Along the sea a second retaining stone wall, about three-quarters of a mile long, and varying in height from 8 ft. to 15 ft., and in thickness from 10 ft. to 15 ft., has been constructed to take the place of a trestle. There are at present ten stations on the line, but other stations will be built to allow of stops about every quarter-mile. At Pemberton the station consists of two 500-ft. roofed platforms between and outside the tracks.

The overhead trolley line is carried upon poles between the tracks (Figs. 342 and 343). The poles are of southern pine, 30 ft. long, 12 in. by 14 in. at the butt, and 10 in. by 10 in. at the head, and are set at intervals

of 60 ft. to 70 ft. on curves and 90 ft. on the straight. At the crossovers the centre posts are 180 ft. apart, and side posts are set at the crossing point to carry a light iron truss over the track. On the the trestles the posts are carried down through the trestle floors and bolted to cross-timbers fastened to the piles. The top of each pole is fitted with a cast-iron grooved cap, the grooves of which carry the six bare copper feeder cables, each of which has a cross-section of 500,000 circular mils and weighs 1.56 lb. to the foot. Each consists of forty-nine No. 10 B. and S. gauge wires laid in seven wires of seven strands each. The poles are placed in

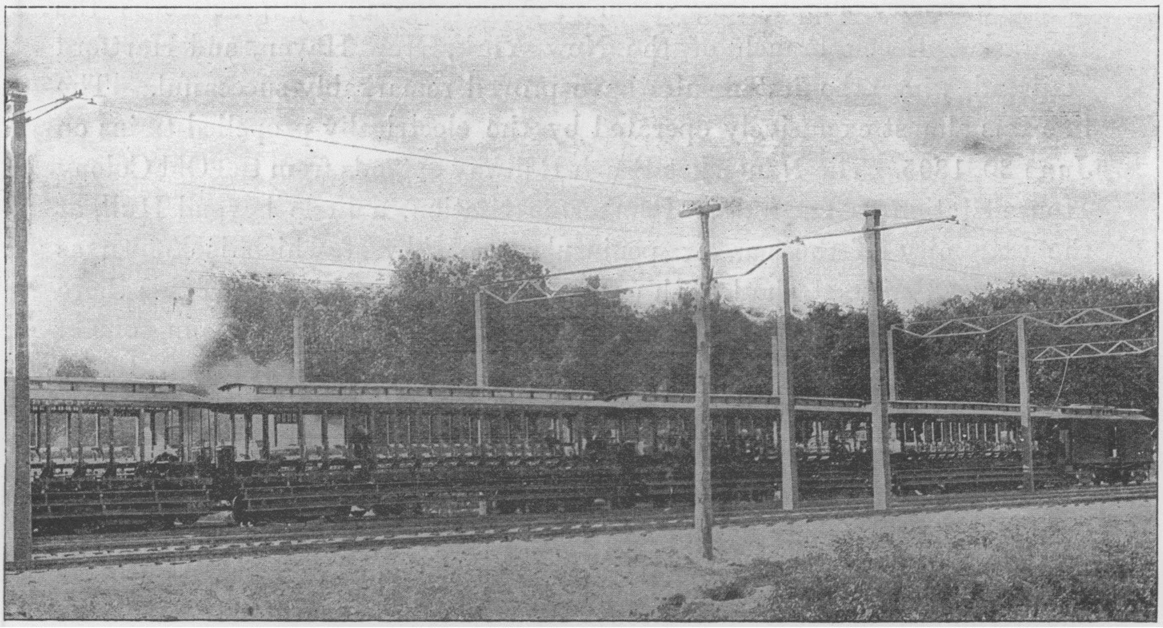


FIG. 342. NANTASKET BEACH ELECTRIC RAILWAY.

wooden boxes filled with concrete, and are set towards the inside track on curves to throw the trolley wire over, and thus provide for the angle of the trolley pole caused by the 4.5-in. elevation of the outer rail.

The trolley wire weighs 1 lb. per foot, and has a cross-sectional area of 330,000 circular mils. The lower surface is almost flat, and provides a large contact surface for the trolley wheel. This form has been given to the wire to permit of more perfect attachment to the hangers, and to prevent the trolley from jumping when passing them.

The brackets, made up of two angle-irons, are bolted across the centre poles and bent and bolted together at the ends. They are kept in position

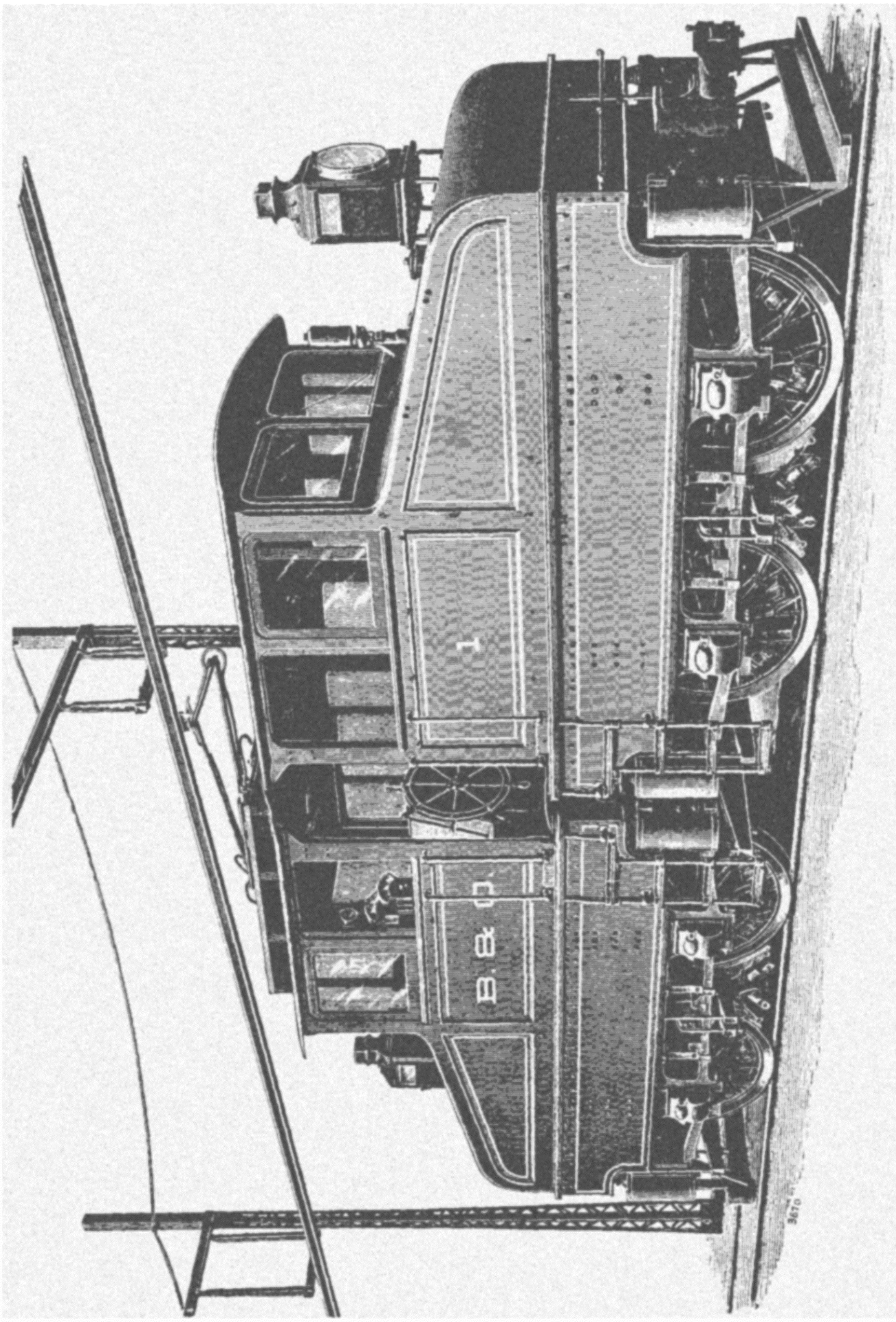


FIG. 331. BALTIMORE AND OHIO ELECTRIC LOCOMOTIVE.

by an iron truss running through the cap. Each hanger is double, and gives an excellent support for the wire. In erecting the trolley wires and setting the poles, steam locomotives were employed. The entire installation is an example of extremely rapid work.

The power-house, known as "Power Station No. 1," of the New York, New Haven and Hartford Railroad, is located 5,900 ft. from the junction with the steam railway. It is a brick station with stone trimming, erected on a rock foundation, and has a slate roof on steel roof trusses. It is 79 ft. by 100 ft. inside the walls, and is divided by a 24-in. brick partition into

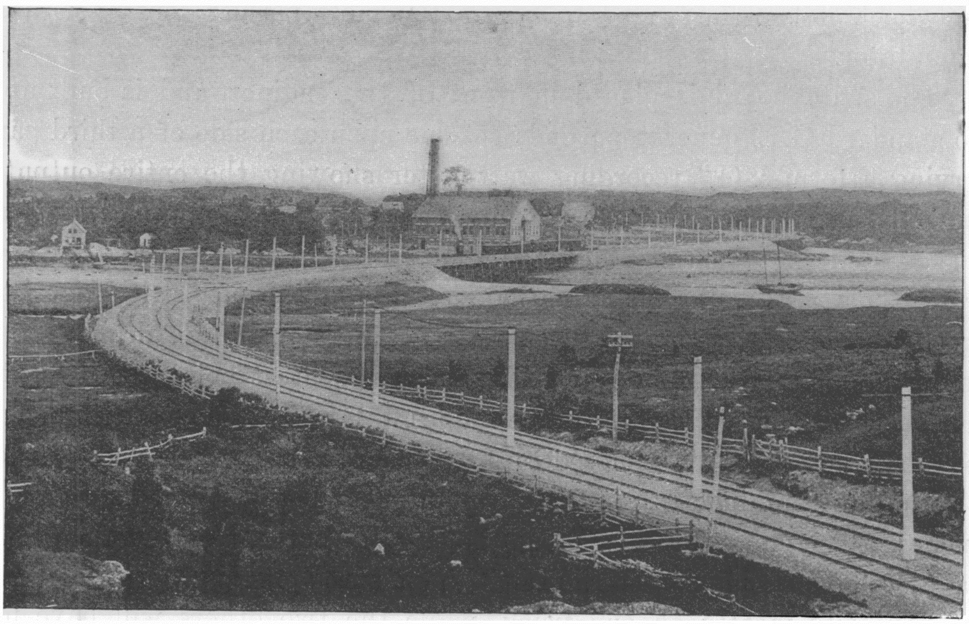


Fig. 343. Nantasket Beach Electric Railway.

engine-room and boiler-room, each 79 ft. by 52 ft. The power-house is provided with a travelling crane of 53 ft. span, the dividing wall being reduced in thickness to accommodate this length of span. The boiler room is equipped with two batteries of four boilers each. The boilers are of the horizontal type, and are 72 in. in diameter, 19 ft. long, with 140 3-in. tubes. Each boiler has a nominal rating of 185 horse-power, but will generate 350 horse-power at 125 lb. steam pressure. The flues enter a 115-ft. circular brick stack, 13 ft. in diameter at the base.

The two engines are of the horizontal tandem compound type by the Providence Steam Engine Company. The shafts are 18 in. in diameter

and carry flywheels 18 ft. in diameter, each weighing 32 tons. The engines can be operated either non-condensing or condensing, and are furnished with automatic safety stops and steam closing mechanism.

The dynamos are direct connected General Electric ten-pole machines having the armature spider keyed to the engine shaft. They are wound for a pressure of 600 volts at no load and 700 volts at full load, and are rated at 500 kilowatts at 100 revolutions per minute. The fields are of cast steel and the armatures are of the "Ironclad" type, each winding being insulated and then imbedded in an insulated slot in the laminated iron armature body. The ten brushes are all operated simultaneously by a handwheel, and are arranged to secure the most perfect contact with the commutator.

The switchboard is placed in front of the engines, and is built up of two standard G.E. generator panels set one upon each side of a third panel carrying a form "G" recording watt-meter showing the entire output of the station. Each generator panel carries a "K" automatic circuit-breaker, and the usual indicating and measuring instruments and switches for the power as well as the lighting circuits. From the switchboard the current passes along a lead-covered cable, set in a $3\frac{1}{2}$-in. drain pipe in concrete to a junction-box at the foot of the nearest pole, up which it is carried in an iron pipe to the feeder cables. Some of the motor cars are closed, others open. The closed cars are heavy goods vans (see motor car at head of train in Fig. 342). The open cars have sixteen reversible benches. The closed motor cars are 42 ft. long over all, and are built extra heavy, weighing when fully equipped over thirty tons each. Two of the four have two motors on one truck, while the two others will have four motors, two on each of the two trucks. The open motor cars have two "General Electric 2,000" machines especially designed for heavy work, and similar to those in successful use on the Metropolitan Elevated Railway of Chicago. They are water-tight and fireproof. The drawbar pull of the double motor cars is 4,000 lb., that of the cars equipped with four motors 8,000 lb. These motors are rated at 100 horse-power each, or 2,000 lb. horizontal drawbar pull through a 33-in. wheel. The current is brought to the motors from the trolley wire by means of a trolley provided with a wheel having an extra deep channel through a General Electric series parallel controller, set up on the right-hand side of the platform. This controller is known as type "L," and is somewhat larger than the "K 2." It embraces the magnetic blow-out principle and all the other excellent

features of the "K 2." The resistances are suspended beneath the car. Two controllers go to each car.

Immediately to the left of the controller is the air-brake handle. The compressed air for the brakes and whistle is furnished by an oscillating cylinder air compressor operated by an electric motor, which is controlled by a special automatic rheostat which regulates the action of the motor in accordance with the pressure in the tanks. A magnetic cut-out is also provided for the air compressor motor. In the case of the closed cars the air pump is set just within the door; in the open car it stands on the platform to the extreme left of the motor-man.

Behind the motor-man and just under the hood is the car cut-out, which in this case is an automatic circuit-breaker similar in type to that used on the generator panels in the station.

Two 15-in. foot gongs are furnished to each car, and on one side, near the centre of the car, on the roof is a chime whistle operated by compressed air. The open cars are lighted by 18 incandescent lamps, and the closed cars by six. Each car has safety fenders placed beneath the platforms.

A feature of the line construction is the system of interlocking switches by means of which the overhead switch is thrown at the same time as the track switch. The trains will be run as accommodation or express, the express trains consisting of a closed car with open trailers. The accommodation service is worked by single motor cars. The traction weight of the closed car is increased by the freight they carry, and the light trains are operated without difficulty. The tests made on this line are of considerable interest. The first showed that the motor car alone, or with a small load, could run at a higher speed than that attained by ordinary express locomotives, and maintain the speed without apparent effort. Subsequent tests were made with the locomotive or closed motor cars as a freight hauler, and no less than 15 heavily loaded freight cars were easily moved along the line at a high rate of speed. A crucial test was made on June 27, when a long train consisting of a motor car, 30 gravel cars, fully loaded, and a brakeman's van, was run over the line at a high speed. The line was opened for regular passenger traffic with the electric cars on Sunday, June 30, 1895. We are indebted to the American *Street Railway Journal* for the foregoing description.

It may be interesting to note, in connection with the preceding description, that American railroads are evidently alive to the fact that electric street railways are depriving them of a very large part of their

suburban traffic, especially where trolley and steam roads operate parallel lines. On one route the total number of passengers carried by the steam railway for six months in 1894 was 243,000, and in 1895 it had decreased to 112,628, or a loss of over 53 per cent.

The great Pennsylvania Railroad Company already owns several electric trolley lines, and is at the present moment engaged in transforming a number of its branch lines from steam to electric. It has just constructed an eight-mile trolley line between Mount Holly and Burlington, a distance of about eight miles. Heretofore the regular locomotives have been running over this line both for freight and passenger service, but the regular passenger traffic is now handled by electric motor cars. Span wire construction is used throughout. The poles are of chestnut, and are all planted 6 ft. 1 in. below the level of the rail. Over three-fourths of the poles are "barreled," and in some places the poles were pointed and worked down through quicksand and water. The top of every pole is exactly 25 ft. from the top of the rail, and on the poles which are used to carry feeders, the cross-arms are placed 24 ft. from top of rail. Two feeders are employed, each 500,000 circular mils. One runs the full length of the road, and the other three-fourths of the way. These cables were strung by a construction train composed of a flat car, a pile-driver car, and a locomotive. The span wire which supports the trolley-wire is $\frac{3}{8}$-in. galvanised standard cable, fastened to $\frac{5}{8}$-in. drop forged eye-bolts. The trolley-wire is No. 00 hard drawn copper, and was stretched by another construction train, composed of a tower car and engine. On the front of the tower car was a stand for the reels, from which the wire was run up to the roller on top of the tower, and fastened to the span wire by loops of wire, until the entire reel was run off. The slack was then taken up, after which the train was run over the line again, to enable the insulators and ears to be put in place. The track is the same as used for the steam road, with the exception that the joints are bonded on the outside of the rail, and a supplemetary wire is run along on each side of the track. The power plant is located at the Mount Holly terminus, and consists of a Westinghouse direct-coupled generator and compound engine and a Climax boiler of 300 horse-power capacity. There are three motor cars of sufficient power to draw standard Pennsylvania Railroad coaches, and maintain a speed of from five to sixty miles an hour. The motor cars are slightly smaller than the standard Pennsylvania Railroad coach, and have the following dimensions: Length of body in frame, 35 ft.; length over platform, 43 ft. 6 in.; width of car at sills,

9 ft. 4 in. As it is the purpose of the railroad company to haul regular passenger coaches, the motor cars are equipped with the company's standard Janney platforms, couplers and buffers, and have an end entrance for passage from one car to the other. The lighting is by electricity, with lamps along each side of the roof. There are also auxiliary fixtures in the centre for burning oil. The cars are equipped with Central Electric heaters, one under each seat in the passenger compartment, and two in the baggage compartment. The wheels are 36 in. in diameter. The first car was equipped with four 50 horse-power motors, the others with two of the same size. Attached to the front of each truck there is a light iron fender, made on the same principal as the ordinary American locomotive cow-catcher. The cars are equipped with Westinghouse air-brakes, supplied with air by a special compressor, operated by a small electric motor. This motor is arranged to be cut out of service when the nominal pressure has been reached in the reservoirs.

The first elevated railways which proved an undoubted success were those built in New York and Brooklyn many years ago, and which are at present operated successfully by steam locomotives. There are eight of these companies in and around New York, of which number the best known is probably the Manhattan Elevated. This company owns 100 miles of track, including sidings and turnouts, 334 steam locomotives, 1,122 passenger cars, and 29 service cars. During 1894 it carried 202,751,532 passengers, and ran 9,026,586 train-miles. Its capital stock is 3,000,000 dols., and its funded debt 35,885,000 dols. It may be mentioned in passing that the lines of this company were the first on which electric locomotives were tried many years ago, but the apparatus used was crude and experimental. A complete description of this trial is given in the October (1890) number of the Transactions of the American Society of Civil Engineers. The motors, &c., were designed by Mr. Leo Daft (see paper published October, 1889, Transactions of the American Institute of Electrical Engineers).

Electricity as a motive power for elevated roads was not tried again until it was so successfully introduced on the Liverpool Overhead Electrical Railway, which is fully described in a later chapter.

The next successful application of the electric motor to elevated railway work was the Intramural Railway at the Chicago Columbian Exposition in 1893, and fully described in ENGINEERING, vol. lv., page 829. The latest and most improved elevated line is that opened at Chicago in the summer of 1895, and which we will briefly describe.

THE METROPOLITAN ELEVATED RAILWAY OF CHICAGO.—This railway is intended to relieve the heavy traffic between the business centre of Chicago and the vast district lying between the north and south branches of the Chicago River, generally known as the West Side, the population of which amounts to some 800,000. The total length of line and branches proposed is 18 miles, and at the present moment there are some 12 miles in operation. There are 32 stations.

The track is carried by an elevated structure, shown in Fig. 344, and

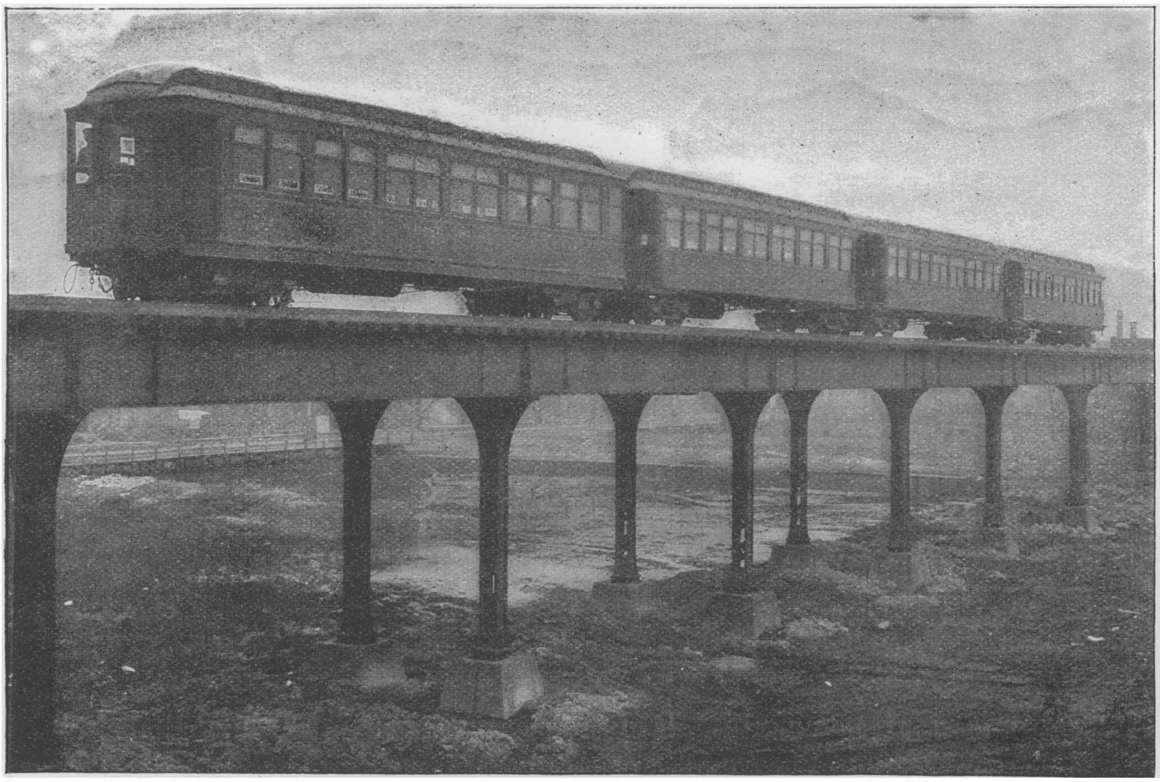


FIG. 344. CHICAGO ELEVATED ELECTRIC RAILWAY.

which is built over land purchased by the company. In this it resembles the railways coming into London.

The elevated railway at Chicago has been much more solidly built than most of its predecessors, as will be seen by Figs. 344 and 345, the latter showing the four tracks and cross-over.

The power-house is 300 ft. long, 90 ft. wide, and 78 ft. high. It has a capacity of 6,000 horse-power, but should the service require, it can be easily increased, as there is land available.

The engines are by the E. P. Allis Company, of Milwaukee. Four units will be installed, two of 1,000 horse-power, and two of 2,000 horse-power. The cylinders of the larger engines measure 36 in. and 72 in., and are 48 in. stroke, those of the smaller 23 in. and 43 in., and 48 in. stroke. The diameter of the shafts of the larger engines is 24 in., carrying 70-ton flywheels 24 ft. in diameter, with rims 21 in. by 20 in., making 75 revolutions per minute. The flywheels of the smaller engines weigh 35 tons, are 17 in. by 17 in. at the rim, 18 ft. in diameter, and make 100 revolutions per minute. Easy access is gained by the galleries to all parts of the engines. Each pair of engines is fitted with two distinct governors, one controlling the point of cut-off, the other connected with a safety valve in

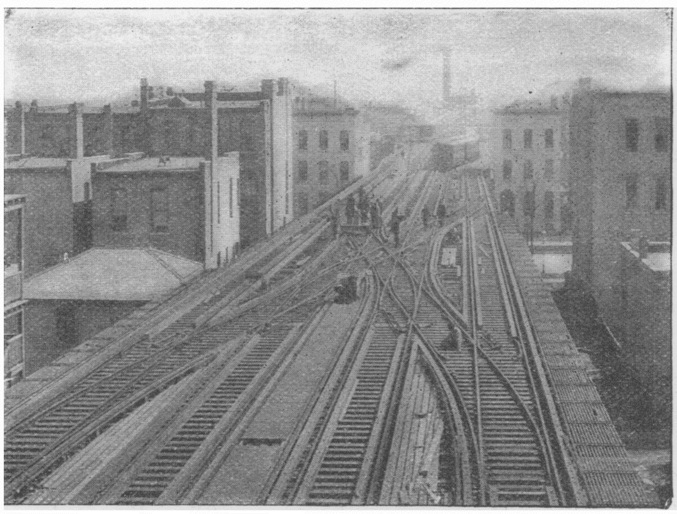


FIG. 345. CHICAGO ELEVATED ELECTRIC RAILWAY.

the main steam pipe. This is closed the instant the speed exceeds a certain number of revolutions. All engines have steel crossheads, and are fitted with the most improved oiling devices. The engines are also fitted with a receiver of large volume between the high and low pressure cylinders. This receiver is of wrought iron, and is carried in a horizontal position, supported with brackets attached to the engine frame.

The boilers are 12 in number, and are by Babcock and Wilcox. Each boiler has a capacity of 300 horse-power, and is provided with a Babcock and Wilcox mechanical stoker. They are divided into six batteries of two boilers each, and are designed for a working pressure of 165 lb. The furnaces are provided with smoke-consuming devices, which work so far satisfactorily.

The entire electrical equipment, generators, motors, and accessories, was furnished by the General Electric Company of America. The dynamo plant consists at present of two 1,500-kilowatt generators similar to those now operating the Brooklyn City Railroad, of Brooklyn, N.Y., and the People's Traction Railroad of Philadelphia, and two 800-kilowatt generators similar to those in the electric railway power stations at Buffalo and St. Louis.

These generators are of the standard General Electric type. The fields are constructed entirely of steel. There are 12 pole-pieces in the 1,500-kilowatt machine, and 10 in the 800-kilowatt machine. The armatures are built up of sheet iron laminations which are individually secured to the spider by dovetailed keys. The armature windings consist of hard drawn copper bars, imbedded in mica-lined slots in the outer armature surface. Special provision is made in the construction of the armature cores to insure thorough ventilation. The field spools can be removed without disturbing the field frame, and both armature bars and commutator segments are individually removable. The temperature of these machines is guaranteed not to exceed that of the surrounding atmosphere by more than 46 deg. Cent., while in actual practice the temperature rarely rises above 30 deg. to 35 deg. Cent. Their commercial efficiency is guaranteed to be not less than 94 per cent. Their design is such that they can stand an overload of 60 per cent. for a short time, and they can shift from maximum overload to no load without sparking at the commutators. The machines are set up between the high and low pressure sides of the engine, and are thus inclosed by the engine frames. The dimensions of the generators are as follows:

TABLE XCII.—Dimensions of a Generator of the Type used by the Chicago Elevated Railway.

	M.P. 1,500 K.W.	M.P. 800 K.W.
Diameter of field	15 ft. 10½ in.	12 ft. 6 in.
Width of field...	3 ,, 0 ,,	2 ,, 6 ,,
Diameter of armature...	10 ,, 6 ,,	7 ,, 10½ ,,
Width of armature	6 ,, 0 ,,	5 ,, 1 ,,
Weight of fields	104,600 lb.	60,000 lb.
,, armature	82,100 ,,	46,000 ,,
Total weight of generators	186,700 ,,	106,000 ,,

The rolling stock comprises fifty-five motor cars and 100 trail cars. The salient feature of the motor car is the steel sub-frame which was

thought necessary to enable it to pull six loaded 40-ft. trailers, and also to afford sufficient weight for purposes of traction. For this reason no attempt has been made to lighten the construction of the motor car body and trucks. The weight of the car, exclusive of all electric apparatus, is nearly 40,000 lb., the length of the body is 40 ft., the length of the steel sub-frame, including the oak end-sills, is 47 ft. 3 in., the width at sill line is 8 ft. 7 in., and at the eaves 8 ft. 11 in., the height from rail to top of roof is 12 ft. 10 in. The car is constructed in the usual manner with oak end-sills and six longitudinal long-leaf yellow pine sills and stringers. The end frames are provided with iron plates at sills and uprights to prevent telescoping in case of collision. The two drivers' cabs on each motor car are located in diagonally opposite corners, and are built out on the platform as far as the hood will permit. This construction necessitates the entrance doors being placed next to the corner posts. The doors are sliding, and are pushed back into the cab. This does not interfere with the driver, as the front door is always locked. The exterior is sheathed with narrow beaded poplar in the usual manner, and is painted in a dark brown shade, with decoration in gold leaf. The interior of the car, with the exception of the window blinds, which are of linwood, is finished in quarter sawed oak, carved, thoroughly varnished, hand rubbed, and polished. The seats are arranged longitudinally and covered with rattan. The cars are electrically lighted by incandescent lamps at the lower edge of the deck ceiling, so as to be directly above the seats. The warming in winter will be provided for by a number of electric heaters, supplied by the Central Electric Heating Company, and so arranged that the temperature can be kept at a proper degree.

The steel sub-frames above referred to are constructed with two 9-in. I-beams, located immediately under the side sill of the body; they are connected at the ends by 9-in. channels, to which oak buffer timbers are attached. A $\frac{5}{16}$-in. stiffening plate, secured by rivets to the end channels and I-beams, extends across the frame and under the end sill of the car body, and forms the foundation for the platform floor. The body bolsters are part of this sub-frame. They are box-shaped and built up with 9-in. channels and $\frac{1}{2}$-in. plates. Corresponding in location to the needle beams of ordinary cars, are 6-in. I-beams placed flush with the top edge of the frame. All cross-members are coped where they meet the 9-in. beams, and are secured to these with connection angles. The sub-frame is supported horizontally by a pair of $1\frac{1}{4}$ in. truss-rods anchored to the bolsters, and pass

under substantial queenposts attached to the frame at the intersections of needle beams and slide beams. The couplers are attached to forged brackets secured to heavy radial bars, which are located immediately underneath the $\frac{5}{16}$-in. stiffening-plate above mentioned. One end of each radial bar passes through a slot provided in the bolster, and engages with a turned kingbolt, and the other end is carried by a 4-in. **I**-beam, extending across the frame for this purpose.

The trucks on which these cars are mounted are somewhat on the lines of an engine truck, of equally good workmanship, but better provided with springs (see Fig. 346). The cars are equipped with Westinghouse air brakes. The required compressed air is carried in a storage tank provided under each car, the tanks being charged from a conveniently located plant.

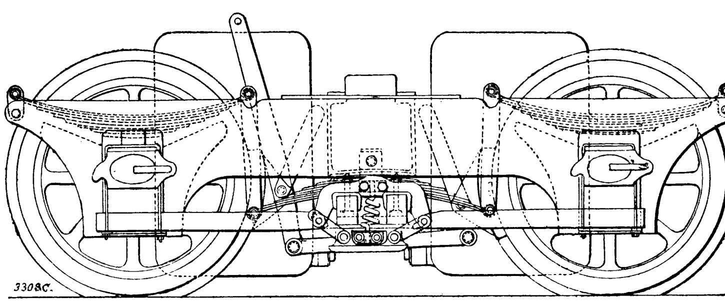


FIG. 346. MOTOR TRUCK, CHICAGO ELEVATED RAILWAY.

The trail cars are supplied by the Pullman Car Company. Each car seats 48 passengers.

The motors employed are of the "G. E. 2,000" type. These are similar in character and construction to the well-known "G. E. 800" heretofore described, but proportionately heavier. Two motors are used on each motor car (see Figs. 346 and 347). The controller is of special design, and is known as the "L" controller of the General Electric Company. It is constructed upon the same principles as the "K" controller, but designed for heavier service. In the operation of the controller, when a quick start is desired, the handle is brought round one-half turn to the right, thus bringing the motors into multiple at full speed. If the start is to be the ordinary gradual acceleration, the handle is moved half a turn to the left, and the motors brought up to half-speed; another turn in the same direction throws them in multiple, and they move forward at full speed. The arrangement is such that each motor takes an equal portion of the load, and this is one of the most important factors in traction work.

The reversing switch is arranged at the side of the controller, and is capable of movement from and toward the motors, and is equipped with a safety locking device. This renders the reversal of the motors impossible should the controller handle not be in the off position. As in the "K" controller, the "G. E." magnetic blow-out is used. The rated capacity of each motor is 100 horse-power under normal conditions, and 150 horse-power for short periods. The maximum rated speed is between 35 and 40 miles an hour on straight and level track. The motors are single reduction, 33 in. high, and 50 in. wide over gears. The field frame is of steel, and the armature is "ironclad," with series, single-turn, drum-windings. The windings are held in slots in the outer surface of the core. The insulation both in the

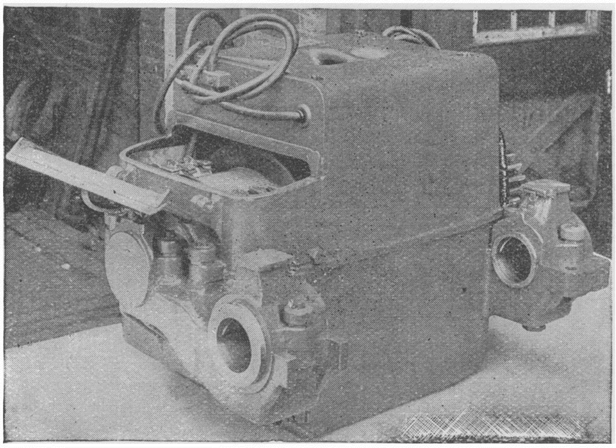


FIG. 347. "G. E. 2,000" MOTOR, CHICAGO ELEVATED RAILWAY.

armature and field is asbestos and mica, thus making a practically fireproof motor. Two doors at the commutator end allow easy access to the interior. Two of these motors are mounted on one of the four-wheel trucks supporting each motor car. From the generators the current is led over insulated copper cables to the switchboards, which are built up of General Electric standard generator and feeder panels. Each of the former is equipped with the necessary field rheostat, lightning arrester, voltmeter, plug switch, and positive and negative main switches, both single-pole. In addition it carries a Weston illuminated dial ammeter and an automatic circuit-breaker, which breaks the generator circuit instantly should a dangerous overload be thrown upon the machine by accident. The equalising switch is mounted on a pedestal near the generator, and the length of the equaliser is thus reduced. The field rheostat and lightning arrester are set at the back of

the board, the former being operated from the face by a handwheel. A discharge resistance is attached to the field rheostat to cushion the discharge when the field switch is opened. It is connected in series with a pilot lamp in front of the panel. The lightning arrester consists of an ironclad electro-magnet in the field of which are two carbon points separated by a $\frac{1}{32}$-in. air gap. The points are connected between the generator lead and ground; the magnet is between the generator and line, the induction of its windings affording additional protection to the generators against lightning. The lighting switch is single-pole and quick break, and is connected to the negative terminal main switch. The positive side of the lighting circuit is connected through a magnetic cut-out to the equalising bus-bar. Current

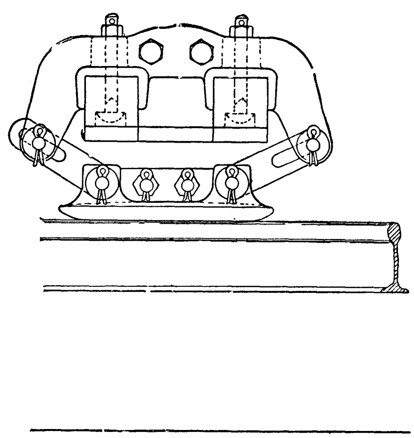


Fig. 348.

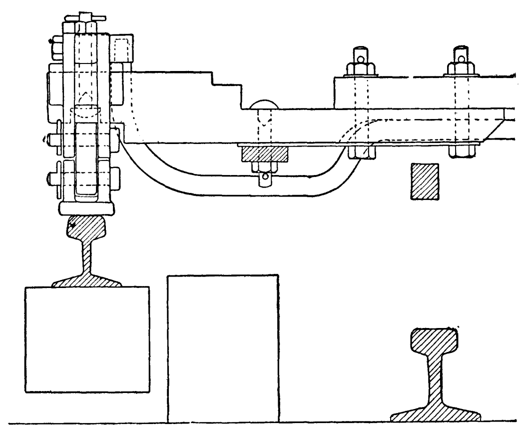


Fig. 349.

Contact Shoe, Chicago Elevated Railway.

can therefore be supplied for lighting purposes from any generator whether its circuit-breaker or main switch is opened or closed. The voltmeter is a Weston illuminated dial instrument, which is connected by the insertion of a plug in the four-point connection in the front of the board, two of the points of which are connected to the generator between it and the main switch, the other two to the voltmeter bus-bars.

The feeder switchboard is divided into a separate panel for each feeder. The overhead line is divided into sections, and each panel corresponding to any one section is equipped with its own circuit-breaker. Each panel also carries a Weston ammeter and quick-break switch. In addition, the main switchboard is equipped with a recording wattmeter, indicating the total output of the station.

Current is taken from the third rail by a contact shoe, illustrated in Figs. 348 and 349, which hangs from an oaken beam projecting from the sides of the truck. The shoe is suspended by means of links which allow of its accommodating itself to any unevenness of the rail or track. Each motor truck is equipped with two of these shoes, one on either side. Going north, the right shoe is in contact; going south, the left shoe. The road has no loops at the terminals. The trains consisted at first of one motor car, fitted up as a smoking car, and three trailers. Each motor car, fully loaded and equipped, weighs 63,500 lb.; each trailer car, loaded, 46,000 lb. With the two motor cars and three trailers the speed is 13 miles an hour, measured on the tangents of the Garfield Park line, including stops of

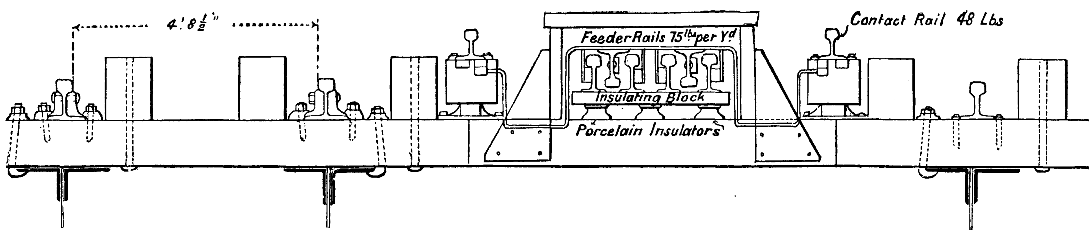


FIG. 350. CROSS-SECTION OF ROADWAY, CHICAGO ELEVATED RAILWAY.

15 seconds each at stations approximately 2,000 ft. apart. The present plans contemplate the eventual adoption of six-car trains, made up of one motor car, equipped with four "G.E. 2,000" motors and five trailers. The average speed of these trains will be 15 miles an hour, including stops.

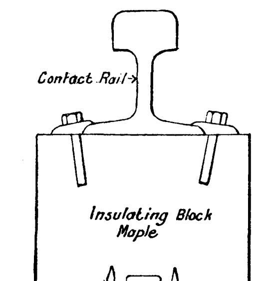


FIG. 351. CONTACT RAIL AND SUPPORT, CHICAGO ELEVATED RAILWAY.

To propel such a load requires probably more current than can be taken from an ordinary trolley wheel and wire, which is one of the reasons which has led to the adoption of a third rail system similar to that used on the City and South London, the Liverpool Overhead, and the Chicago Intramural. The cross-section of double tracks is shown in Fig. 350. The contact rails are shown supported on insulating blocks just outside the central guard timbers. The contact rail weighs 48 lb. per yard, being thus equivalent in conductivity to a copper wire about 1 in. in diameter. Instead of using ordinary copper feeders, steel rails laid in a special trough between the tracks are employed, as shown in Fig. 350.

Connections between these and the contact rail are made through copper wire soldered to special rail bonds. Fig. 351 shows cross-sections of the insulated block and malleable iron stool supporting the contact rail. The circular groove in the bottom of the block forms a drip edge which prevents surface leakage from the contact rail to the iron stool. The insulating blocks are made of well-dried maple boiled in paraffin. The malleable iron stool has a circular lug driven into the centre of the block, to which, however, it is also fastened by wood screws.

The feeder rails employed are of a very poor quality of steel, which is very cheap, but which, as far as conductivity is concerned, is quite as good as the best steel. These are supported on blocks set on porcelain insulators, and the joints are bonded with copper bonds. These feeders are covered by a wooden box, the top of which forms a convenient walk between the tracks. Where crossovers occur, these feeder rails are replaced by heavy copper cables.

The return current is made through the track rails and steel structure. Each rail, besides being bonded to the next rail, is bonded to the iron girders, and the latter are also bonded one to another, thus making a very excellent return circuit.

CHAPTER XXV.

BRITISH ELECTRIC RAILWAYS.

THE DUBLIN ELECTRIC SYSTEM.—The Dublin Electric Tramway was opened for traffic on May 16, 1896, the Board of Trade inspection having taken place on the 7th. Starting at the Addington Road, about half a mile from the centre of Dublin, it runs past the show grounds of the Royal Irish Society at Balls Bridge, then through Merrion and Booterstown to Blackrock and Dalkey. The map (Fig. 352) shows the route.

The total contract for permanent way and equipment was filled by the British Thomson-Houston Company, Limited. The line is $7\frac{3}{4}$ miles long and fairly level, the heaviest gradient being 1 in 16. It is double track throughout, with the exception of two short lengths. The rails are of the ordinary girder type, and weigh 76 lb. per yard. The gauge is 5 ft. $2\frac{3}{16}$ in. The overhead trolley wire system has been adopted throughout; the suspension being by means of span wires stretched across the street, with the exception of a short piece of line near Dalkey, where double bracket-arm poles placed between tracks have been adopted. Fig. 353 shows the centre-pole system. Double insulation has been used throughout, the well-known "Ætna" insulators being employed. The poles, brackets, and all line material were supplied by Robert W. Blackwell, of London.

The system of generation and distribution of the electrical current is most interesting. The whole of this plant has been designed by Mr. H. F. Parshall, consulting engineer to the British Thomson-Houston Company, Limited, whose work in connection with electric traction and dynamo design is so well known.

The power-house (Figs. 354 to 357) is on the bank of the River Dodder, whence water for condensing purposes is obtained. Fig. 358 shows the interior of the main power station.

There are three Babcock and Wilcox 250 horse-power boilers, with double steam drums, the normal pressure being 140 lb. per square inch. These are fed by Vicars stokers. The gear for these stokers is driven by

a "G. E." shunt-wound motor, which also drives the scrapers of the Green's economiser. The speed of this motor can be regulated by means of a rheostat. Feed water is supplied either by an injector, or by two three-throw pumps, made by Daniel Adamson and Company, each of which is driven by a "G. E." motor, of the same type as those used on the cars, but shunt wound. All motors in the boiler-house are worked from the switch-board bus-bars at 500 volts, through special rheostats and switchboard. The feed pumps are capable of supplying 16,000 lb. of water per hour.

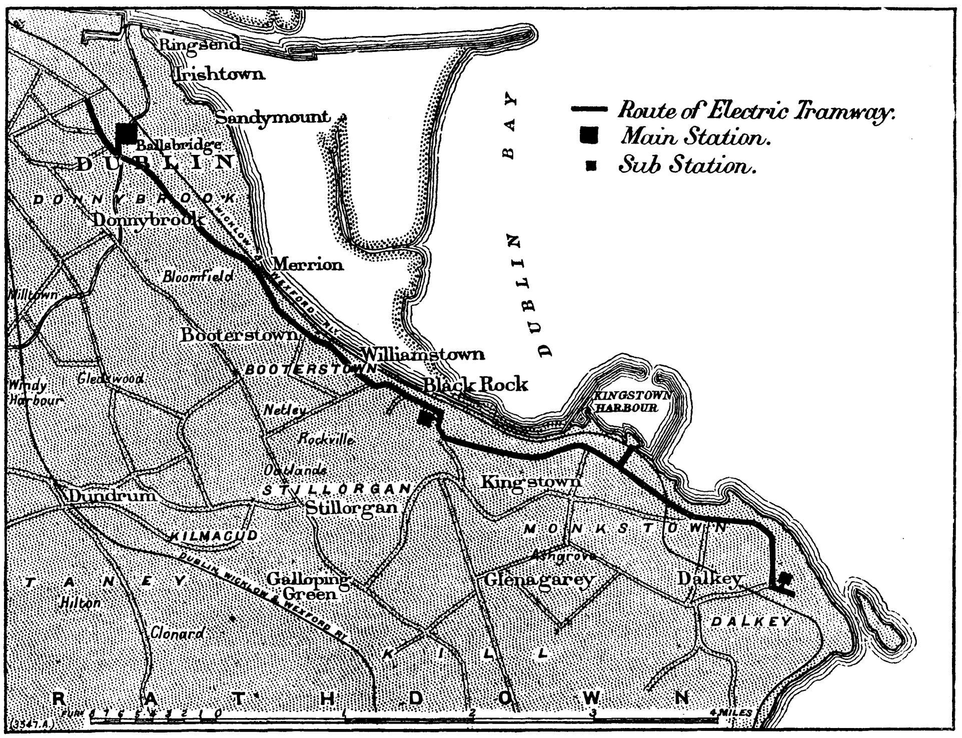


FIG. 352. PLAN OF DUBLIN ELECTRIC TRAMWAYS.

The feed water is taken either from a large storage tank, direct from the town supply, or from the hot-well of the surface condenser, and is passed through a Green's economiser of 192 pipes. An octagonal brick chimney, 111 ft. 8 in. in height, and 6 ft. in diameter at the top, carries off the furnace gases after they have passed through the economiser flues.

A ring main steam pipe collects the steam from the three boilers. This is 8 in. in diameter, and of mild steel. The tee pieces and bends are cast steel, and the branch pipes to the engines are copper, $4\frac{1}{2}$ in. in diameter. The stop valves in the main ring and at each branch are of the

Hopkinson pattern, and arranged so that any defective section of the plant can be shut down without interfering with the working of the rest.

In the engine-room there are at present four 150 brake horse-power Willans (H. H. S.) compound condensing two-crank engines, running at 380 revolutions per minute, with a steam pressure of 140 lb. These engines will develop 175 brake horse-power for a short time on occasion. The engines are adapted to belt driving, each being provided with a 3 ft.

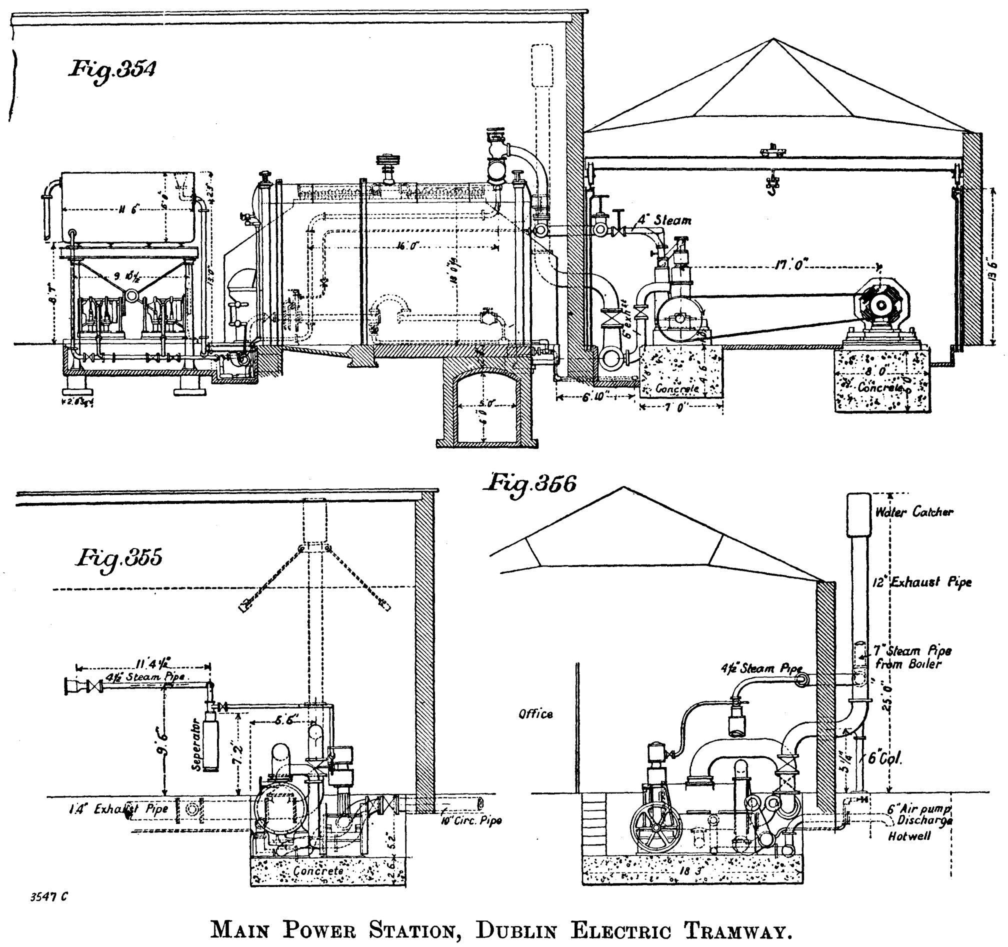
Fig. 353. Centre-Pole System, Dalkey.

10 in. flywheel pulley, and with an outer bearing. Two ot the engines drive two B. T. H. 100-kilowatt four-pole tramway generators at 625 revolutions per minute. These are compound wound for 500 volts at full load. The two other engines are belt-connected to two six-pole three-phase generators, each capable of developing 120 kilowatts at from 2,300 to 2,500 volts, running at 600 revolutions per minute.

The transmission and distribution of electrical power is on what may be termed a "mixed system," that is, it is a 500-volt continuous-current system for points near the power station, and 2,500 volts three-phase

transmission to more distant sub-stations, in which latter the higher potential is transformed into a continuous 500-volt current for the trolley wire.

The considerations leading to the use of this "mixed system" were the location of land belonging to the tramway company, and available for power-house and car-shed, the considerable length of line, and the Board of



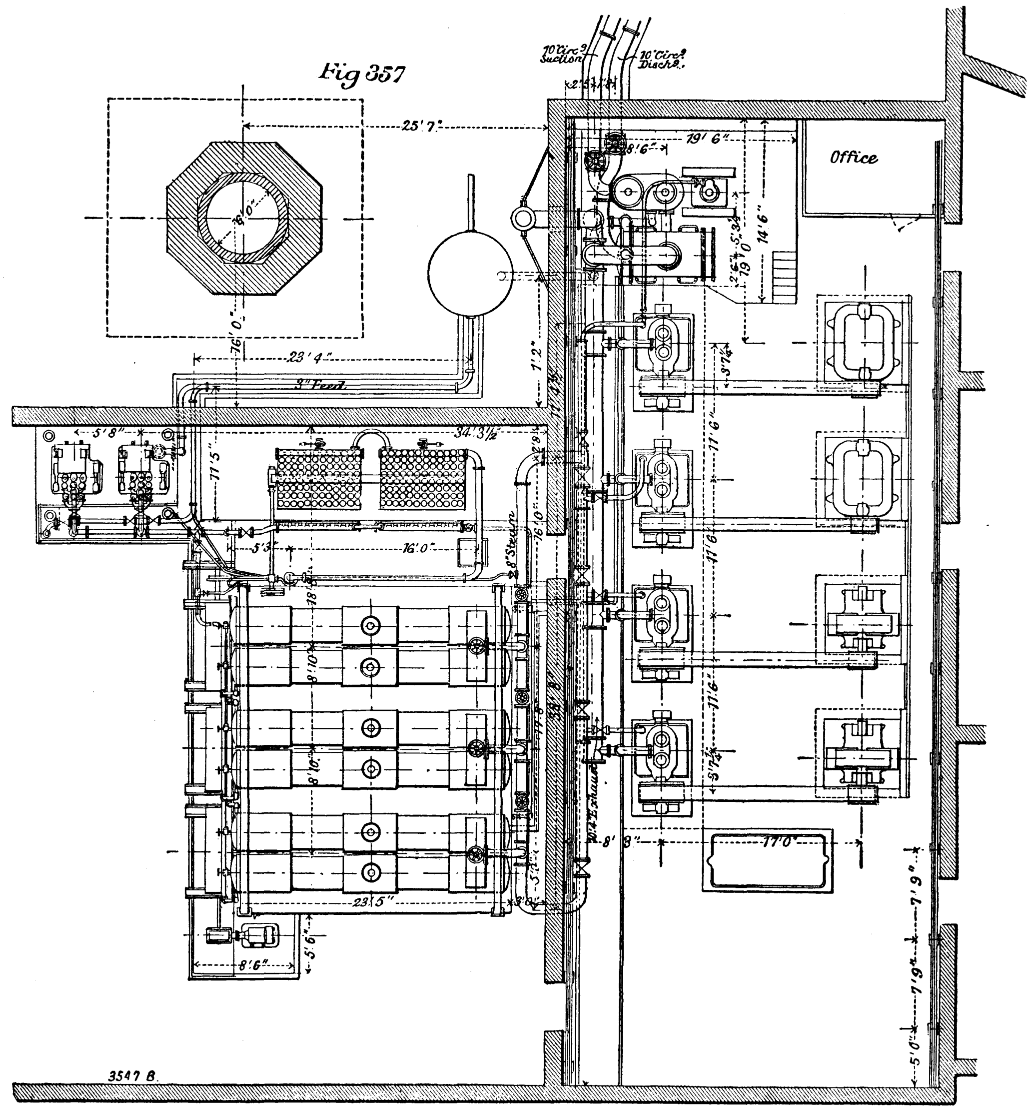
MAIN POWER STATION, DUBLIN ELECTRIC TRAMWAY.

Trade rules as to the permissible drop in voltage in the return circuit through the rails.

Purely commercial reasons led to the utilisation of the property at Balls Bridge as the main power station and central point of the system. A station nearer the middle of the line would have been more desirable from an electrical standpoint, considering the length of line at present equipped. Inasmuch as extensions will probably be made into Dublin, which would

consume a considerable portion of the total output of water, the electrical disadvantages at present incident to the Balls Bridge site near the Dublin end of the line may disappear when the system is completed.

The Board of Trade regulation as to the return circuit is that the drop



Main Power Station, Dublin Electric Tramway.

shall not exceed seven volts. With twenty-five motor cars and trailers operated over the present route by current supplied at 500 volts from Balls Bridge, the drop in the return circuit between the extreme end of the line at Dalkey and the generating station would several times exceed the limit

set by the Board of Trade. It became evident, therefore, that to comply with these regulations while using the Balls Bridge site, it would be necessary to have high-tension transmissions to two or more points along the line. The company owned two suitable properties, one at Blackrock and one at Dalkey. At each of these points sub-stations were established, receiving energy in the form of three-phase 2,500-volt current at a periodicity of thirty complete reversals per second, this current driving at each sub-station two synchronous alternating-current motors, each of which

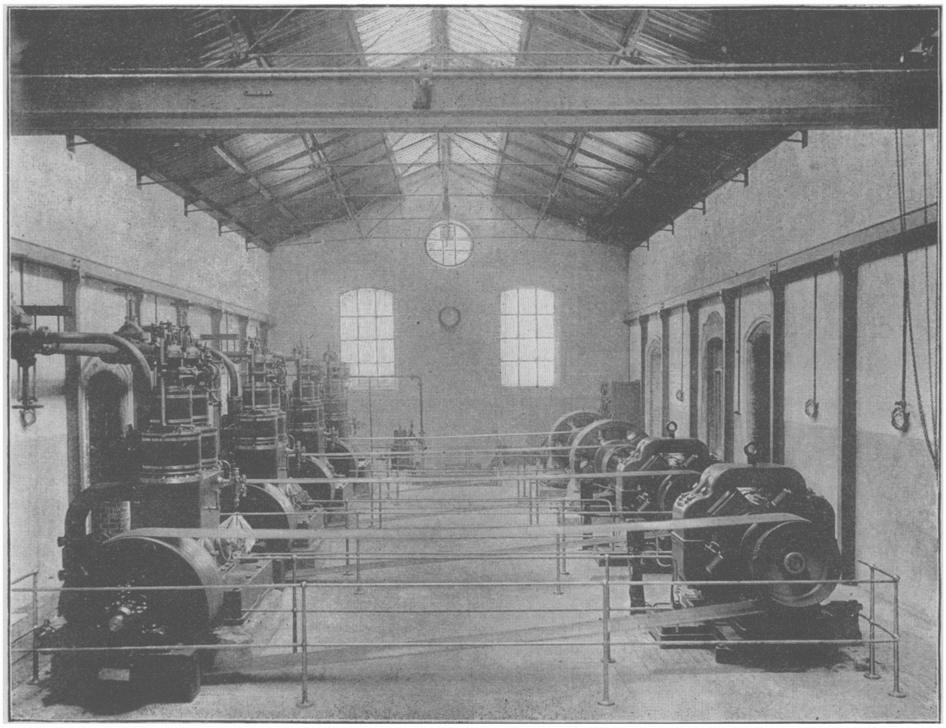


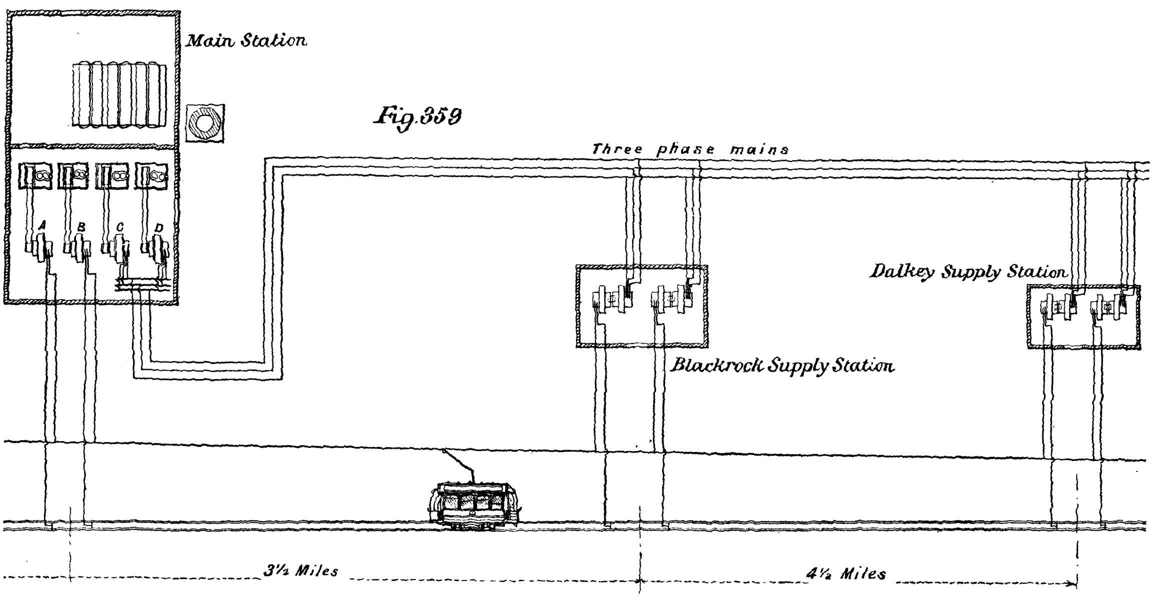
Fig. 358. Interior of Main Power House.

in turn drives a four-pole 500-volt railway generator. Each motor-generator set has an output of 120 amperes at 500 volts. In the diagram (Fig 359) are shown two generators (A and B) supplying current direct to the trolley system. These machines are of 100 kilowatts capacity each. Machines C and D are three-phase machines. The type of three-phase machine used is shown in Figs. 360 and 361.

Some of the practical advantages of this system are that by its use double the present number of cars can be operated without breaking the Board of Trade rule; that the three-phase method of distribution requires

about three-fourths the weight of copper which would be required by a simple alternating-current system of the same voltage; that the motor-generators may be run from either the 500-volt continuous or the 3,000-volt three-phase mains; that, by the use of the synchronous motor, the phases of the alternating currents can be so governed that the amount of power delivered to any sub-station can be regulated as desired.

The convenience and flexibility of the motor generator method of transmitting power is quite apparent when it is borne in mind that the reaction on the field of the synchronous motors can be compensated for by



System of Current Distribution, Dublin Electric Tramway.

a few turns of wire in series with the armature of the generator to which it is coupled, thus keeping up the counter electromotive force of the motor, and insuring that under no circumstances whatever can the motor be thrown out of synchronism. The combined efficiency of the motor generator set is 85 per cent. at full load. Another feature of the station which gave great satisfaction was the operation of the switches on the three-phase circuit. They consist of three switches coupled in parallel, and operated through wooden connecting-rods about $3\frac{1}{2}$ ft. long; their efficiency was tested by repeatedly breaking the circuit. No instance of an arc being maintained is yet recorded.

The 7 volts drop limit in the return, fixed by the Board of Trade regulations, is principally for the protection of gas and water pipes from electrolytic effects. By restricting the voltage drop in the earth return, the currents return to the generating source through the rails. With a single point of distribution all of the return currents are toward the station, but with several points of distribution, as in the Dublin system, the return currents at different points along the line are in different directions at different times, according to the distribution of the loads. Hence, with the same difference of potential in the earth return as in the former case, the possibility of trouble from electrolysis is greatly lessened.

At the Balls Bridge main power-house, there are two 500-volt continuous-current railway generators supplying current to points within

Fig. 360

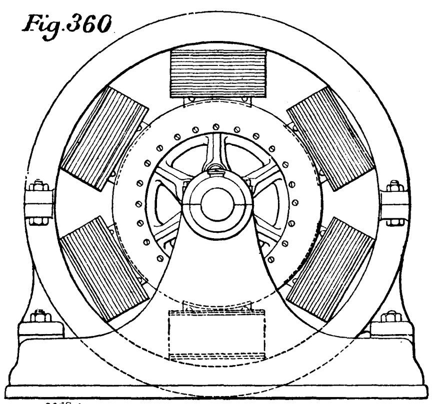
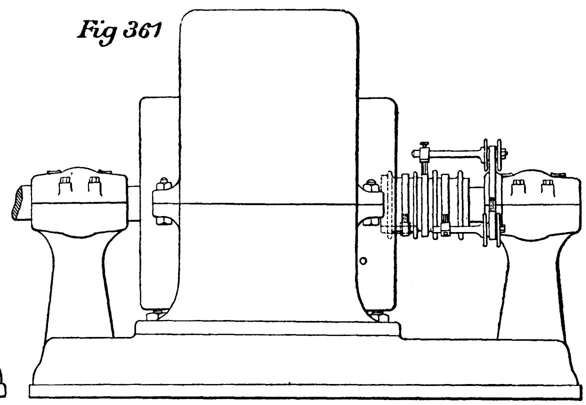


Fig 361



THREE-PHASE GENERATOR, DUBLIN ELECTRIC TRAMWAY.

two or three miles of the power-house. These are connected direct to the trolley line feeders and to the earth return through the switchboard. These generators are of the four-pole compound-wound type, and will withstand changes of load of 125 kilowatts without sparking.

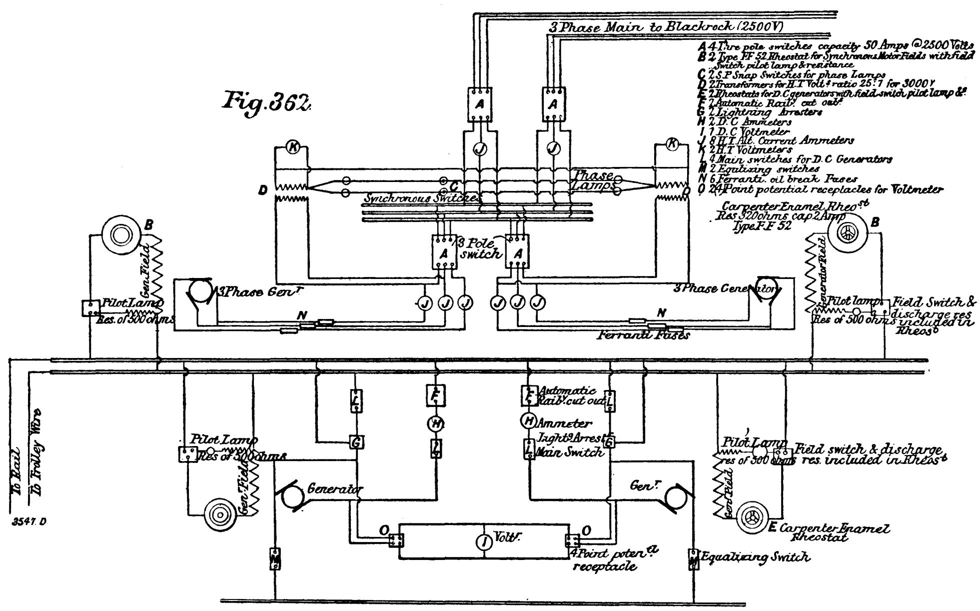
The switchboards are fitted with magnetic circuit breakers that are adjustable to open at any desired output of current.

The three-phase installation consists of two 120-kilowatt six-pole generators. These machines are remarkable for their solidity and simplicity of construction, and are so designed that they will withstand 50 per cent. overload for a considerable time without dangerous heating. The armatures consist of a cast-iron spider, on which are mounted the armature cores consisting of sheet iron stampings .014 in. thick, 20 in. long, and having six distance blocks $\frac{3}{8}$ in. wide to provide for ventilation. The armature coils

are formed on wooden moulds and then laid in slots in the periphery of the armature. They are held in position by wooden wedges, and the coils are Y-connected. The end connections are protected by brass shields. The field magnet poles are composed of laminated iron plates $\frac{1}{16}$ in. thick, cast into a cast-iron yoke. The rise of the temperature after 14 hours' run at normal capacity is 20 deg. Cent.

The three-phase switchboard (Fig. 362) carries switches for cutting out either of the generators, and also for cutting out either of the two triple concentric cables extending from the switchboard to the Blackrock sub-

Fig. 362.



SWITCHBOARD CONNECTIONS, DUBLIN ELECTRIC TRAMWAY.

station. Two concentric cables are used, so that in case of failure of one the system may be still kept in operation. Synchronising mechanism for putting the two machines in parallel is also provided. Ampere meters are placed in each of the three circuits, so that the distribution of the current between the three circuits can at any time be noted.

The field magnets of the three-phase generators are laminated, and the coils are excited from the 500-volt continuous-current generator bus bars.

This station also comprises a motor-generator and a motor-generator switchboard for charging the accumulators used in lighting the power-house and cars and for supplying any current required when the large generators

are not running. This motor-generator has an efficiency above 85 per cent. at full load, and is remarkable for smoothness of running and absence of heating and sparking.

At the Blackrock sub-station, the situation of which is shown on the plan, Fig. 352, there is storage for a number of cars, and also shops for work incidental to the operation of the tramway.

The two 60-kilowatt four-pole railway generators are direct connected on the same foundation to the two three-phase motors. These are of the same type as the generators. During the tests which were made on this system, the railway generators which are directly coupled to the three-phase motors were directly short-circuited, and also run for some time at 60 per cent. overload, but under no circumstances was it found possible to pull the synchronous motor out of step. The switchboard has two panels for the distribution of power from the 500-volt generators. On the three-phase part of the board there are five three-phase switches, one for cutting out each of the cables coming in from Balls Bridge, one for cutting out the cable that extends on to Dalkey, and one for cutting out each of the synchronous motors.

In each of the circuits are measuring instruments, so that the current in any one may be measured at any time.

The three-phase synchronous motors are excited by means of the 500-volt continuous-current machine, These three-phase motors are self-starting, but, owing to the disadvantage of the three-phase or three-legged rheostat for the 2,500-volt circuit, the machines are brought to speed by means of the continuous-current generator used temporarily as a motor, and driven from the 500-volt trolley line which receives this starting current from the main power station at Balls Bridge. This is the *modus operandi* of starting up one sub-station when neither of the machines are running. When one of the machines is running the current for starting the other is, of course, supplied by it.

On the switchboard at Blackrock there is also the necessary apparatus for synchronising the three-phase motors with any other three-phase machines operating in the system.

The sub-station at Dalkey is to all intents a repetition of that at Blackrock, the only variation being that at Blackrock the operation of the Dalkey sub-station can be more or less controlled. The Blackrock sub-station, being nearest the centre of the line, is used as a point of distribution to the Dalkey station.

The whole three-phase installation has been so laid out that if there were a temporary failure of any machine or cable, the connections could be arranged between the sub-stations so that the system could be kept in operation and within the limits specified by the Board of Trade.

The motors used in the Dublin cars are of the "G.E. 800" type, which, being translated, means that they were developed by the General Electric Company of the United States, and are rated to exert a horizontal effort of 800 lb. on a 33-in. car wheel at 8 miles per hour. Therefore the total horizontal effort of a double motor equipment of this type is 1,600 lb.

Two of these motors are capable of moving a 10-ton train at a speed of 8 miles per hour. Of course this weight of train is in excess of ordinary tramway requirements. The difference in power is allowed for the acceleration of the train. Owing to the stringent regulations of the Board of Trade as to the maximum speed permissible in electric tramway practice, the designing of these motors for a high rate of acceleration has been a problem of special difficulty. They are steel-cased and waterproof, essential conditions for good tramway service. The use of steel in construction lessens the weight, so that a motor capable of exerting 25 horse-power, complete with its gearing and other accessories, does not exceed 1,500 lb. This is a most important feature, for with the old style of heavy cast-iron motor, deterioration of metals and rolling stock was much more considerable than it is to-day.

The armature of the motor is ironclad. The coils are formed interchangeable, insulated with asbestos, so as to be fireproof, and finally so treated as to be waterproof. The magnet coils are also fireproof and waterproof, and the lower coil is encased in lead, so as to be oilproof. It has been found that oil is frequently more disastrous to the durability of the coils than moisture. The journals are of bronze. The pinion is of steel, and the gear iron. The ratio of reduction is 4.78 to 1. The gears are carried in oil-tight cases, supported by the frame of the motor. The addition of this gear case has increased threefold the durability of the gears. The lubrication of the motor is automatic, and is accomplished by means of special grease boxes, oil being unsuitable on account of the shocks to which the motors are subjected. The motors are carried in the method known as the crossbar spring suspension, and the construction of truck is such that any unpleasant oscillation of the car is prevented. The trucks have been especially selected for uniform and easy motion.

The trucks employed are of the type known as the "Peckham Standard Cantilever Extension," which have already been fully described in a previous chapter. The dimensions are as follows:

	ft.	in.
Length of solid forged top frames	14	0
" spring base (centre to centre of end springs) ...	12	8
" wheel base (centre to centre of wheels)	6	0
Height of truck with 30-in. wheels	2	$3\frac{1}{2}$

These trucks are provided with the "Peckham" flexible gear and dust-tight self-lubricating journal-boxes.

Rigid steel collars are pressed upon the axle by an hydraulic pressure of 10 tons, and carefully machined so as to give the proper distance for the motor bearings. To provide for wear the rigid collars are fitted with flanges, to which are bolted sectional washers constructed in halves. When worn out these sectional washers can be easily and cheaply replaced by new ones. Below the collars and washers is inserted a packing of fibre or paper to take up the lost motion when the washers are only partially worn. The rigid collars prevent the necessity of cutting grooves in the axles and the use of the ordinarily-used loose collars, thereby giving a stronger axle and preventing any loose bolts.

Improved lever brakes are used. The brake beams are manufactured from the best quality of wrought-steel bars and carefully machine-fitted. The connecting bolts are machine-turned and case-hardened, to insure accurate fit and prevent wear. The leverage is 10 to 1.

The brake guides are provided with removable repair pieces, to take out lost motion as they become worn, so as to prevent noise. They are provided with positive pull-back coil springs for releasing the brake shoes from the wheels. The brake shoes are furnished with the well-known Christy head, and are so constructed as to be interchangeable and easily removed without loosening any bolts.

Each motor truck is provided at either end with a "Peckham" adjustable life and wheel guard, furnishing a simple, flexible, and effectual guard to prevent persons who may fall in front of the car from being run over by the wheels. These guards can be arranged to work any desired height above the track. At Bristol, where the same trucks and guards have been used, a fatal accident was prevented, within a few days of the opening, by the efficient operation of the guard: a child who fell in front of the car while at full speed having been picked up by the lifeguard without injury.

The controller used to govern the car-motors is the General Electric Series Parallel Controller, type K 2, already fully described in an earlier chapter.

The bonding of the rails for the return circuit has also received very careful consideration. The particular system of power transmission and distribution already described has had the effect of rendering the bonding of the rails comparatively simple, so far as Board of Trade requirements are concerned. In order, however, to insure durability, the current density in the contacts, apart from the question of the drop in volts per mile, should be considered with the greatest care. In the present system the current density per square inch of contact between the bond and the rail

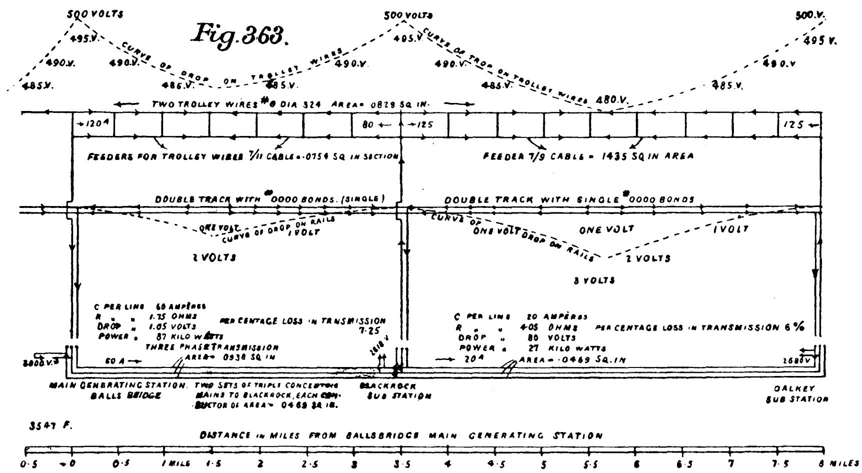


DIAGRAM SHOWING DROP OF VOLTAGE, DUBLIN ELECTRIC TRAMWAY.

has purposely been kept low, so that any electrolytic or local action might be prevented. The fishplates have been supposed not to possess any electrical conductivity, and, in fact, tests have shown that the resistance per mile of track closely agrees with the resistance of the metals plus the connecting bonds themselves, so that the fishplates could not be depended upon as a part of the electrical contact. The bonds used are of the "Chicago" type, which has been very widely used in the United States. All the bonds are painted with P. and B. compound, which is an acid and alkali-proof paint, and possesses highly insulating properties.

Fig. 363 shows the result of the calculations which were made to ascertain the fall of potential in the return circuit and to fix the amount of bonding required. As there are three stations, one main and two sub-stations, there are two points of maximum drop. During the tests which

were made preliminary to the Board of Trade inspection of line with 20 motor cars and 20 trailer cars on the line running on schedule time, the maximum drop of voltage obtained was 1.6 volts, whereas the Board of Trade rules admit as much as 7 volts. The leakage current from the rails through the earth was found to be under 1.8 per cent. of the output. Mr. Parshall has made a most exhaustive series of tests on this system, which we understand will be published later.

In Fig. 364 we give a view of the Blackrock sub-station, showing the

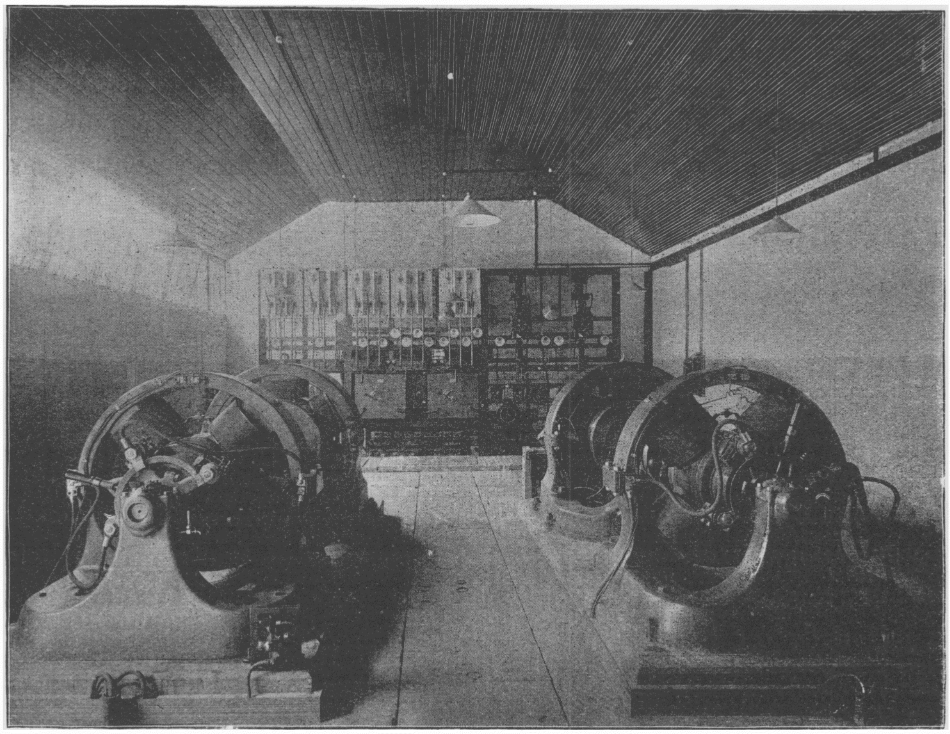


Fig. 364. Blackrock Sub-Station, Dublin Electric Tramway.

two direct-current transformers. Each of these consists of a three-phase synchronous alternate current motor, designed to work at 2,000 volts, and coupled direct to a 60-kilowatt continuous current dynamo. The two armature shafts are connected by a flexible coupling. To start the transformer, the continuous current machine is connected up with the main 500-volt feeder, and its speed gradually increased to the proper point by adjusting the starting resistance and field rheostat. The field of the alternate circuit motor is then excited, and when the synchronising gear shows that the proper phase has been attained, the main switch connecting

the motor to the high-tension feeder is closed, and the transformer is then ready to supply current to the cars. The switchboard arrangements at this station are shown in Fig. 365. The three-phase mains are led into the station through the 50-ampere switches shown at A on the left, and leave by a similar switch on the left. These mains are coupled up to the three-phase bus-bars shown and to transformers at D, which reduce the voltage to a suitable amount for the phase lamps used in synchronising the motors. Voltmeters for this synchronising current are shown at L. The three-phase mains pass from the bus-bars to the motors through the 50-ampere

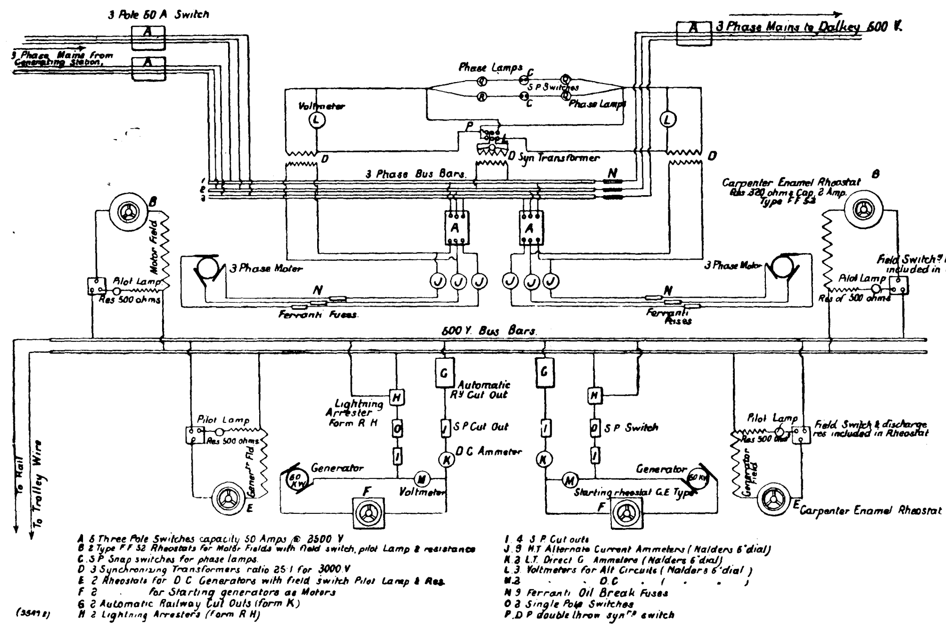


FIG. 365. SUB-STATION SWITCHBOARD CONNECTIONS, DUBLIN ELECTRIC TRAMWAY.

switches shown, whilst Ferranti fuses N and Nalder alternate current meters J are interpolated on each of these mains between the above-mentioned switch and the motor. Coming to the direct-current circuit a rheostat B, field switch pilot lamp and resistance is placed across both the motor and generator fields. On the generator circuit is rheostat F, used in starting generators as motors. A voltmeter M is placed across the terminals of the generator, and interpolated in its circuit on the way to the 500-volt bus-bars are cut-outs I, and single pole switches O, lightning arresters H, an automatic railway cut-out G, single pole fuses I, and ammeters K. A section of the three-phase main cable is shown in Fig. 366. These cables

were supplied by the British Insulated Wire Company, and are of the concentric type, there being three separate copper conductors, two of which are annular. The section of each is $\frac{1}{20}$ square inch. They are cased in lead and armoured with steel. The insulation is of paper. Designed for a working load of 3,500 volts, they were tested before leaving the factory up to 12,000 volts, this pressure being maintained for 15 minutes, and after laying they have been tested in place up to 5,000 volts. Some $11\frac{1}{2}$ miles of this cable have been laid.

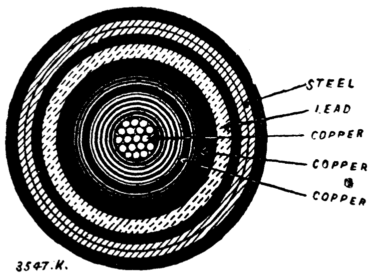


Fig. 366. Concentric Three-Phase Feeder Cable, Dublin Electric Tramway.

The trolley is of the Blackwell swiveling arm type, and so arranged as to little interfere with the seating capacity. The head is completely insulated from the pole. The wheel is mounted on a pivot, and so fitted that its centre is level with or below the end of the pole, in order that if the wheel leaves the wire it cannot catch in span wires or bracket arms. The connections are so fixed that no twisting strain is brought upon the wire or cable between wheel and standard. The construction is such as to make it impossible to fix the wheel in any but a vertical plane. The pole is insulated with rubber tubing, and is composed of thin steel tubing. It is insulated from the socket in which it is held. The socket is mounted pivotally on ball bearings, and the electrical connection between fixed and rotating parts is so arranged as to avoid any danger of the cable being twisted off. The springs are such that a pressure of from 20 lb. to 28 lb. can be maintained between trolley wire and wheel. The electrical connections are easily accessible. No springs are employed to keep the trolley pole in any special position. It follows the wires at all times solely by the upward pressure of the wheel.

Bristol.—The tramway system in Bristol has grown from very small beginnings. In 1875 the first section of line was acquired by the present Company.

The first step taken to bring about the Kingswood extension was in 1891, when a provisional order for carrying out the work was obtained; but it was not until the modified regulations, recommended by the joint Committee of both Houses of Parliament, to operate electric traction were known, that the Bristol directors felt justified in entering upon the project.

The directors then instructed their then engineer, Mr. Joseph Kincaid, M. Inst. C.E., to carry out the works, which he has done most successfully. The necessary powers to enable the company to proceed with their scheme of electric traction for the Kingswood Tramway were obtained in 1894. The subject received all the attention its importance deserved, alike from the Corporation of Bristol and the Local Boards of St. George and Kingswood, through whose district the line runs. Independent investigations were made by each body to arrive at a thoroughly impartial decision on the merits of the whole case. In each instance the decision was entirely favourable towards the proposed mode of traction.

In the St. George and Kingswood Electric Tramway the most modern system was adopted under the best expert assistance available, and the British Thomson-Houston were selected to carry the work into operation. In this extension pretty nearly every difficulty to be met with in construction work had to be encountered.

Both at Kingswood and St. George there is every sign of vigorous growth in population and trade, value of land along the line has in many cases doubled, and the prospects have brightened as it is recognised that by the electric tramways now opened for passenger traffic, a stimulus has been imparted to the district. The public rejoicings attending the formality of opening the new line are a significant sign of the times, and the sympathetic interest awakened in electric traction augurs well for its rapid growth in this country.

To enable the company to comply with the new regulations of the Board of Trade, not only was very careful workmanship required, but certain special appliances were needed which will be described later. It is well known that the opposition to electric traction on the part of the General Post Office authorities, and particularly of the Telephone service, was caused chiefly by the fear of disturbance on their wires; and it must be conceded that their mistrust was not without foundation. But, with care, these disturbances can be reduced to such an extent as to be practically innocuous. The chief object of the new rules is to insure that no prejudicial effect shall take place, and arrangements are made for acertaining and recording the source of any disturbance during the whole period of work. It is evident that the company itself will benefit by these precautions. The principal causes of disturbance are induction and leakage, but probably trouble is more frequently due to the latter. Leakage means loss of power, and, consequently, unnecessary outlay; so that any operation which tends to

diminish leakage will also effect a pecuniary saving. The Board of Trade insists that "a continuous record shall be kept by the company of the difference of potential during the working of the tramway between the points of the uninsulated return furthest from and nearest to the generating station." When the difference exceeds seven volts it must be reduced, or the working of the line stopped. In another clause it is stipulated that the insulation of all feeders and conductors shall be so maintained that the leakage shall not exceed $\frac{1}{100}$ ampere per mile of tramway. The electric line commences at the western, or city, end of Old Market Street (see Fig. 367), where it joins two lines of horse cars. There is a double track for most of the route, and at the starting point there are four roads, with cross-overs to suit any arrangement of traffic. The power-station, which is in Beaconsfield Road, a turning south of the main road, close to St. George's Church, is about equidistant from the extreme ends of the line. On leaving Old

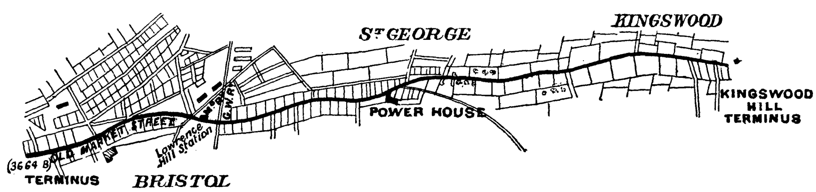
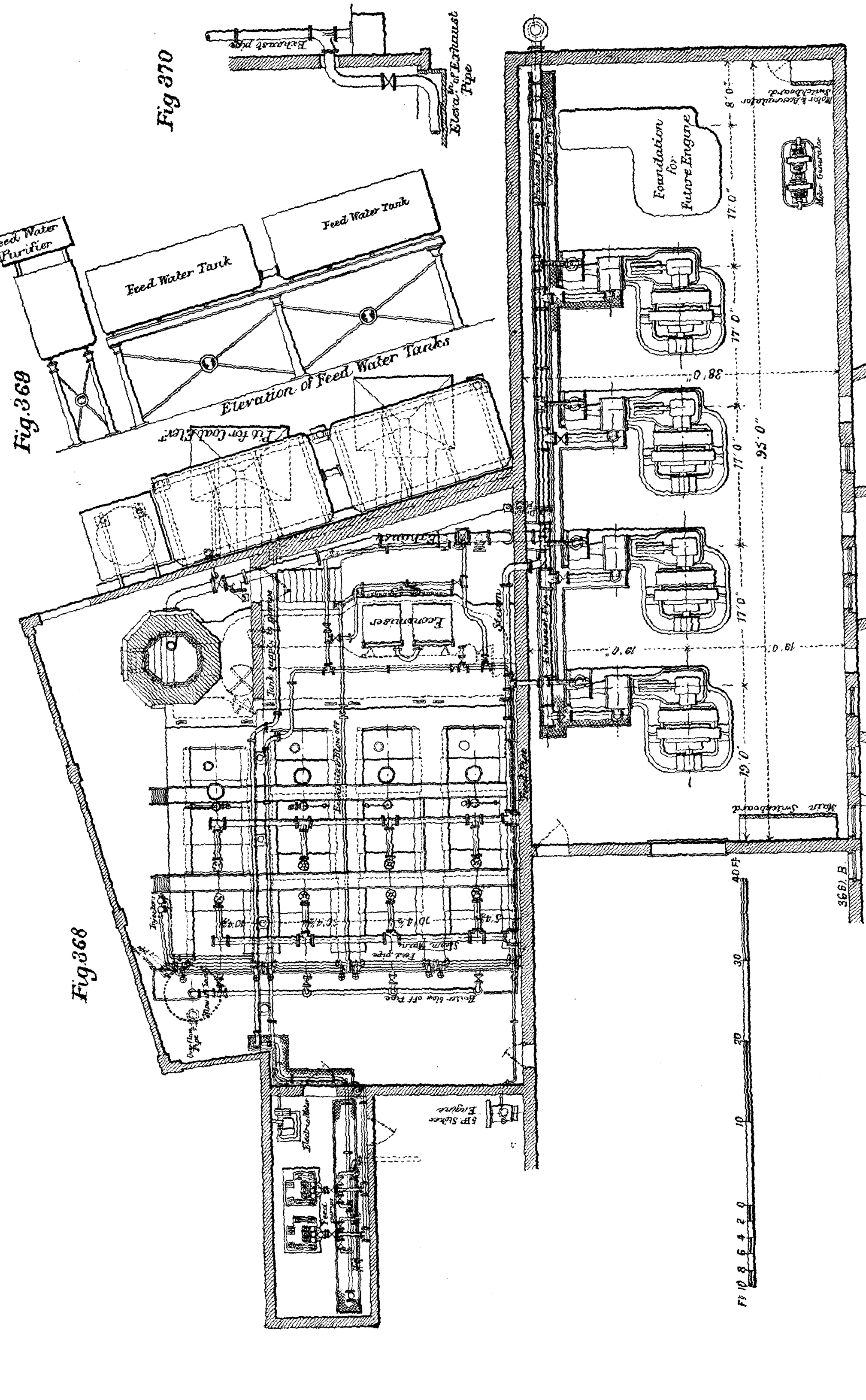


FIG. 367. PLAN OF ROUTE.

Market Street the line continues in an easterly direction, *viâ* Lawrence Hill and Redfield Road, to the London Road and Kingswood, a total distance of four miles. About 660 yards from its commencement, the new electric line now under construction to Fishponds branches off to the left, and three-quarters of a mile from the starting point, the road crosses the South Wales branch of the Great Western Railway. Up to this point the gradients are fairly easy, except one short length of 1 in 32. After crossing the railway, there are several inclines of 1 in 30, 1 in 32, and 1 in 35. Just before reaching the points leading into the power station, there is an incline of 1 in 15 for a length of 220 yards. After passing the dépôt there are gradients of 1 in 17 to 1 in 20, and the road continues to rise till within half a mile of Kingswood terminus, where it has an elevation of 300 ft. over the starting-point in Old Market Street. The last half mile is slightly down hill.

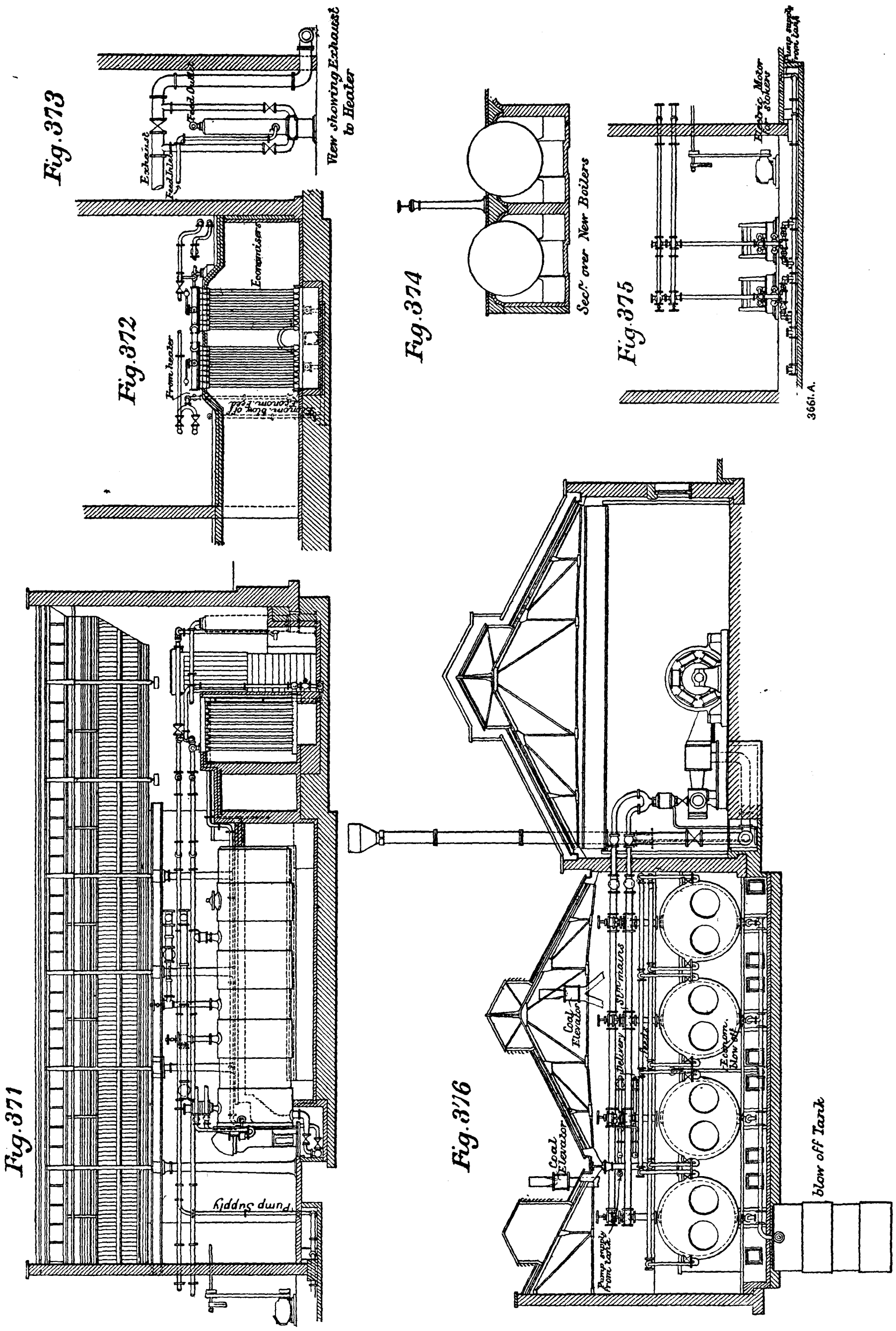
The illustrations, Figs. 368 to 376, show the general arrangement of the enlarged power station. The greater part of the ground on which this stands

Fig. 368 · Fig. 369 · Fig. 370



Plan of Bristol Electric Tramway Power Station.

was previously occupied by a tramway stable and car-shed, and, wherever possible, the existing buildings have been utilised. The only additional



SECTIONS THROUGH VARIOUS PARTS OF BRISTOL ELECTRIC TRAMWAY POWER STATION.

ground required was the portion adjoining the pump-room ; but the engine and boiler houses have been re-roofed and the car-sheds slightly extended.

It has been necessary to lower the floor of the car-sheds considerably, in order to obtain sufficient headway.

The contractors for the engines, boilers, dynamos, and other electric appliances and machinery, as well as for thc cables and cars, were the British Thomson-Houston Company. There are four Lancashire boilers of Siemens-Martin steel, the manufacturers being Messrs. D. Adamson and Company. The length of boilers is 30 ft., and the inside diameter 7 ft. 6 in.; the furnace tubes being 3 ft. in diameter. The thicknesses of the plates are $\frac{23}{32}$ in. for the shell, $\frac{17}{32}$ for the furnaces, and $\frac{11}{16}$ in. for the ends. The boilers are fitted with Green's fuel economisers, and four pairs of Vicars' mechanical stokers; the same electric motor which drives the stokers also serves for the scrapers of the economiser. There are two feed pumps, each capable of delivering 16,000 lb. of water per hour, against a boiler pressure of 160 lb. to the square inch, and each of these is driven by a separate electric motor of the "G. E. 800" type, but shunt wound (Figs. 377 and 378). The steam mains are 7 in. in diameter, the pipes leading from the boilers to the mains 6 in., and from the mains to the engines 4 in. All these pipes are in mild steel. The boilers have been tested separately at the factory to a pressure of 260 lb. to the square inch, and the steam pipes, stop valves, &c., to a pressure of 300 lb. The ordinary working pressure is 140 lb. to 160 lb.

As at first designed and constructed, the station was fitted with three Willans' centre valve compound non-condensing engines, with two cranks at 180 deg. apart, and giving 135 indicated horse-power at 380 revolutions, with a steam pressure of 120 lb., though the usual working pressure in the cylinders is 160 lb. The flywheels were 3 ft. 8 in. in diameter, and grooved to take ten $1\frac{1}{4}$ in. Egyptian cotton ropes for driving the dynamos.

There were three 100 kilowatts slow speed continuous-current dynamos, each capable of giving an output of 200 amperes at 550 volts, when working at 650 revolutions per minute.

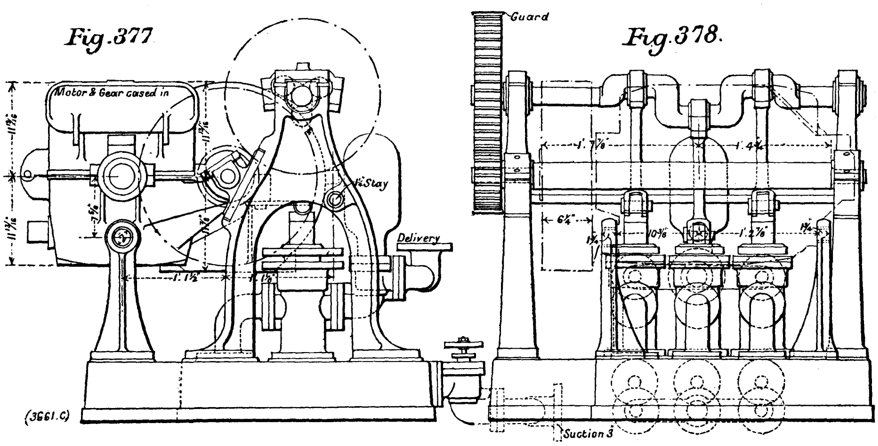
This installation has proved entirely inadequate to cope with the increased service which has been demanded by the public. The number of motor cars, which originally was twelve, has been nearly doubled. An extension of about two miles has just been completed.

This, and the fact that direct driving is much more economical than the use of belts or ropes, decided the Tramway Company to entirely replace the engines and dynamos by an up-to-date direct driven plant. In designing and getting out a specification for the new equipment, the well-

known expert, Mr. H. F. Parshall, was called in to advise; and the station which is now nearly completed, and which in its way will be one of the finest in Europe, owes its origin to him.

After very carefully considering the merits of all the various types of engines existing at the present moment, and which have been applied to traction purposes, it was decided to adopt the McIntosh & Seymour engine. This engine has already been fully described in a previous chapter. The difficulty of construction was very great, owing to the fact that the cars had to be kept running during transformation.

It was decided to put in 150 K. W. direct coupled sets and to add two more Lancashire boilers to the existing two, thus bringing the total number



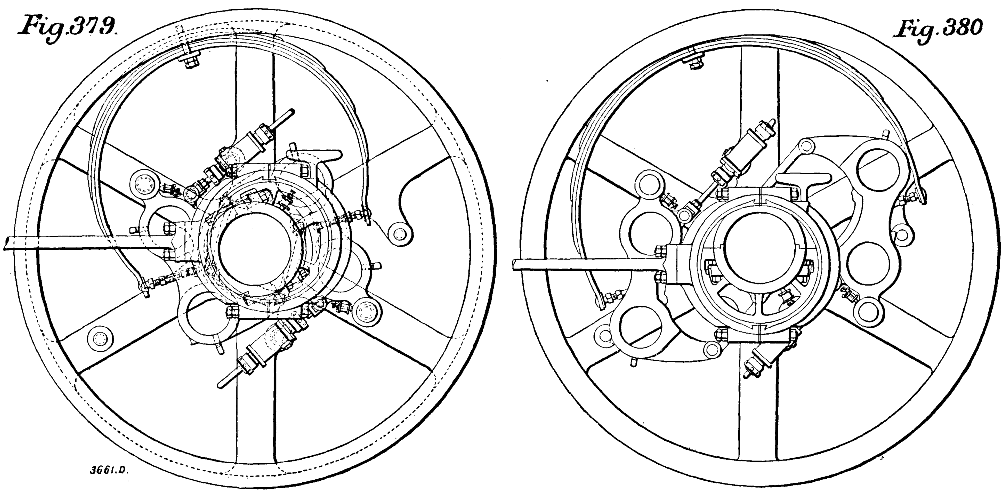
Electrically-Driven Boiler Feed Pumps at Bristol.

up to four. The engines used are direct coupled and horizontal. The diameter of the high pressure cylinder is 13 in., that of the low pressure 23 in., stroke 17 in., revolutions 200 per minute at 150 lb. steam pressure. The economical load is 230 horse-power at one-third cut-off. At four-tenths cut-off, the indicated horse-power is 310, the maximum cut-off being three quarters. The total weight of the engine is 46,000 lb. The weight of each flywheel is 4,500 lb., the diameter being 82 in. The diameter of the main steam pipe is 5 in., and that of the exhaust 10 in. All these engines are absolutely guaranteed to regulate from no load to full load within 2 per cent. variation of speed.

The governor used is shown (Figs. 379 and 380). The position of the centrifugal weights is controlled by a double plate spring, acting through frictionless and hardened steel pins, resting in hard steel cups at

each end. The cups in the weights are so placed that the centrifugal force of the weights is directly opposed by the spring, which avoids pressure or friction on the pins upon which the weights are pivoted. In the construction of the governor, the greatest care is taken. All pins are made of tool steel, hardened and ground, turning in bushes of hard phosphor bronze, with provisions for oiling. The governor can be adjusted as to sensitiveness by changing length of tension pins between weights and spring, which are arranged by a telescope for this purpose, and the speed is regulated by changing weight of bushings in centrifugal weights. The cut-off is varied by turning the eccentric around on the shaft. The pendulum carrying the eccentric is moved by jaws on the weights, so inclined, that while the

Fig. 379. Fig. 380



Governor of the Engines at Bristol.

movement of the weights easily controls the position of the pendulum, the reverse is not true, and the centrifugal weights are free from the disturbing influence of the push and pull of valves. This enables the governor to be adjusted to give practically perfect regulation without becoming unstable in the least.

Stability is obtained by dash-pots attached to the weights.

The governor operates the auxiliary valves only, controlling the cut-off. The main valves are driven by fixed eccentrics controlling the admission of steam, and opening and closing of exhaust. A very rapid opening and closing of the ports is affected by this arrangement, notwithstanding the very small travel of the valve. The auxiliary valve always cuts off the steam at a point near the middle of its stroke, and at cut-offs,

when the piston is moving rapidly, the auxiliary valve is moving in an opposite direction to the main valve.

On compound and triple-expansion engines, by giving different strokes to the auxiliary valves, the cut-offs in each cylinder can be varied so that the work will be divided equally among the cylinders, and the drop in temperature of the steam in each will be equal for any load; hence the engine will always be working under the most economical conditions possible with the work it is doing, without any hand adjustment of the valves. This adds materially to the economy of an engine working under variable loads.

Besides the four main electric generators, there is a motor-generator which supplies current for the accumulators and the lighting of the station. There are four electric motors, of which two drive the feed pumps, one is for the mechanical stokers and fuel economisers, and one for the machinery in the repairing shops. Each of these motors will give up to 20 horse-power if necessary. The motor generator is capable of generating on its secondary terminals an output of 230 amperes at 135 volts; and its general construction is similar to that of the main generators. The motor portion of the motor generator is compound wound in such a manner that the electromotive force at the secondary terminals is constant; but the compounding of the field is done entirely from the motor armature, and not from the secondary armature, so that this latter may be used in connection with the set of accumulators. The primary terminals of the motor generator are connected to the main omnibus bar of the station, and have, therefore, to work at an electromotive force of from 500 to 550 volts. In connection with the shunt winding of the fields of the motor generator, there is a regulating switch with 20 stops, and a suitable resistance, enabling the electromotive force between the terminals of the secondary part of the apparatus to be varied between 135 and 105 volts.

One special feature of this tramway is the use which has been made of accumulators. Of these there are two descriptions, the main, and the car-lighting accumulators, both of which have been supplied by the Chloride Electrical Storage Syndicate. The main accumulators consist of a battery of 55 cells, with 15 plates in each cell. They are of the special protected type, and each cell has a capacity of 546 ampere-hours, when discharging in six hours. The low-tension current for charging these cells is obtained from the motor generator, and from them current is taken for lighting the station when the generator is not in use, and also for charging the

small accumulators for car lighting. The arrangement of switchboard is shown in Fig. 381. As power may be required for the motors, when the main generators are shut down, arrangements are made by which the low-tension current from the cells can be used to drive the low-tension side of the motor generator, giving a high-tension current for the motors.

The arrangement of the car-lighting accumulator switchboard is shown on Fig. 382. The current is supplied to the bus-bars either from the main accumulators or from the low-tension side of the motor generator. There

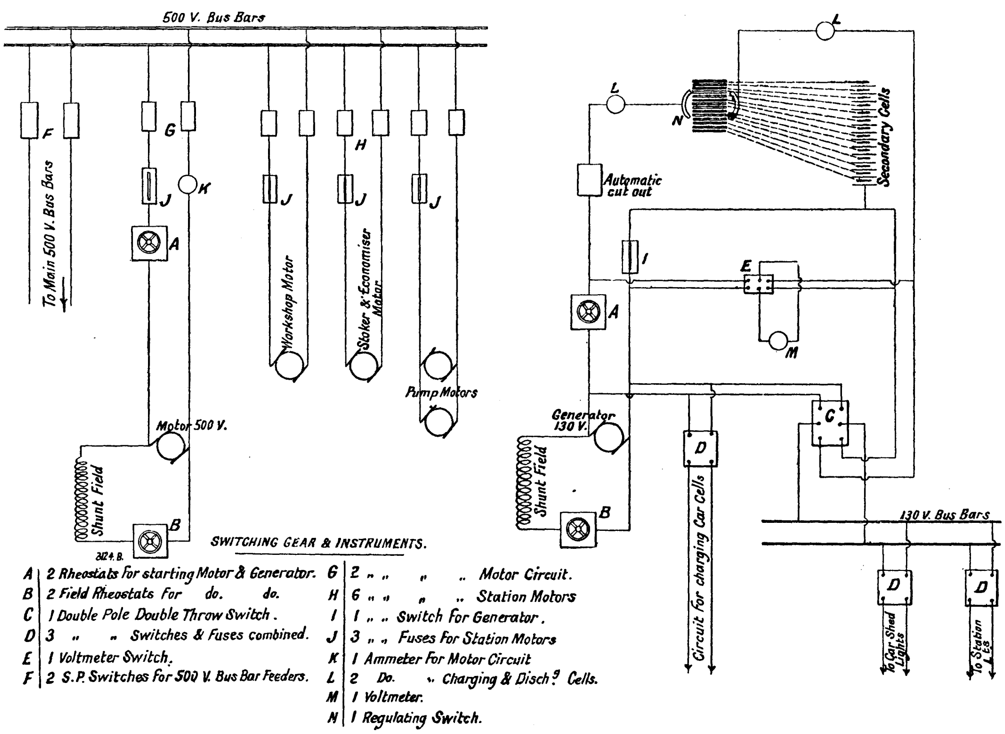


FIG. 384. MOTOR SWITCHBOARD. FIG. 381. LOW TENSION SWITCHBOARD.

are 40 small sets of storage batteries, each set consisting of two boxes, with five cells in each box. As a rule, five sets of small batteries will be joined up in series and charged at once.

Fig. 383 is a diagram showing the connections on the switchboard for the three generators. There are also two feeder panels on the switchboard, but these are very simple, only having a fuse, a switch, and a maximum indicating ammeter on each of the four feeders, which are connected to the positive bus-bar. The switchboard used for controlling the motor generator, and the four motors used in the power station, is shown on Fig. 384.

Fig. 385 shows a special switchboard, arranged in accordance with the requirements of the Board of Trade. This is in permanent connection with

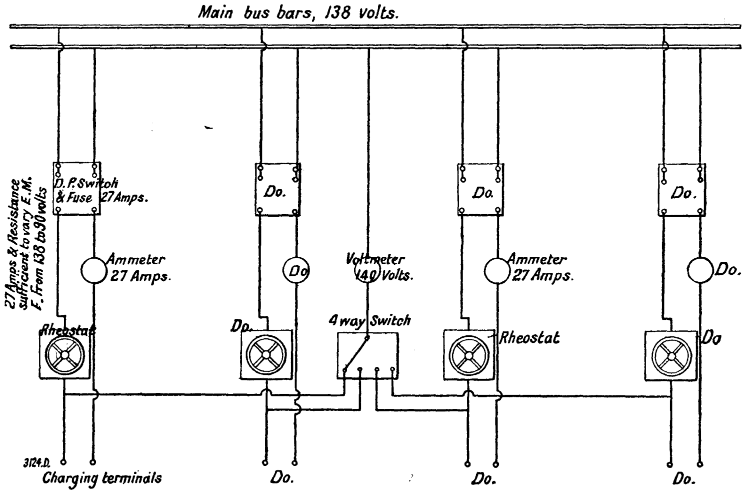


FIG. 382. CAR LIGHTING ACCUMULATOR SWITCHBOARD.

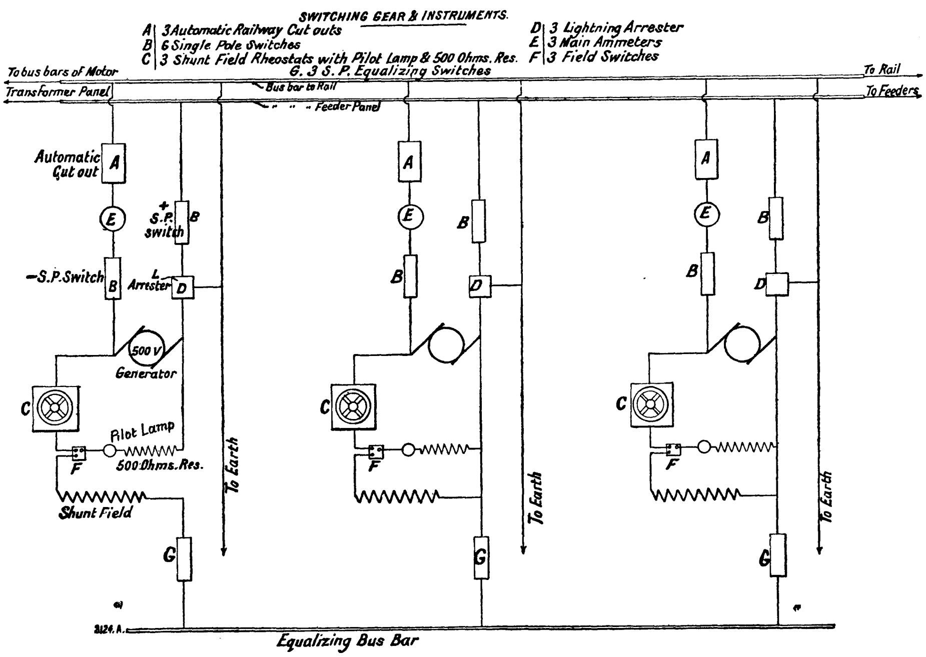


FIG. 383. MAIN SWITCHBOARD.

the trolley wire, the rails, and with a test wire to the extreme ends of the line. It is provided with two 50-ampere main switches and one recording ammeter, capable of reading from 2 to 25 amperes. These two switches are

arranged to receive the conductors from the two earth connections, and on their other sides they are joined to the ammeter, which is connected to the negative bus-bar. There is also a current indicator capable of indicating from one-twentieth of an ampere up to 3 amperes, and from half an ampere up to 10 amperes, with a switch to alter the connections, so that it can be read in either ratio. This current indicator is connected up on one side to the "line" bus-bar, and on the other side it has a portable connection which enables it to be placed in contact with any one of the generators, when switched off from the main switchboard. The test wire, already referred to, which is connected to the extreme ends of the rail return at Old Market-street and Kingswood, is also brought to this board. Between the "rail"

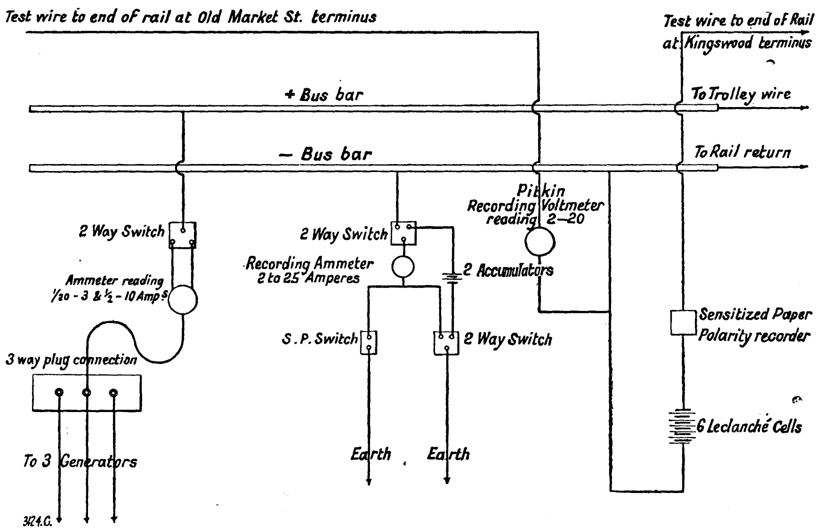


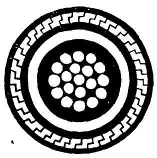
FIG. 385. BOARD OF TRADE SWITCHBOARD.

bus-bar and the Old Market-street wire, a Pitkin recording voltmeter, reading from 1 to 20 volts, is inserted, and records the difference of electromotive force in this part of the rail return. Between the rail-bus bar and the other test wire, a battery of six Leclanché cells, and a sensitised paper polarity-recorder are inserted. So long as the difference of potential between the station and the Kingswood end of the rail return is less than that required by the Board of Trade, the current from the cells is sufficient to send a current through the wire in the opposite direction to the return current, and the polarity-recorder gives a continuous record of the direction of the current.

An armoured feeder (Fig. 386) is taken underground the whole length of the tramway, and is connected about every half-mile to cast-iron pillars;

these contain switches and a lightning arrester between the feeder and the overhead wires. Fig. 387 shows the connection which can be made by means of the switches in these pillars. In addition to the feeder there is a small, three-strand, insulated and armoured conductor, laid the whole length of the line. One of these strands is for the Board of Trade leakage tests, the other two wires are for telephones, instruments being fixed in each of the switchboxes for use by the company in case of a breakdown.

FIG. 386



The cables consist of a strand of high conductivity copper wire, insulated by a heavy sheath of bitumenised fibre, which is then sheathed with a tube of lead, this being made direct on the cable under

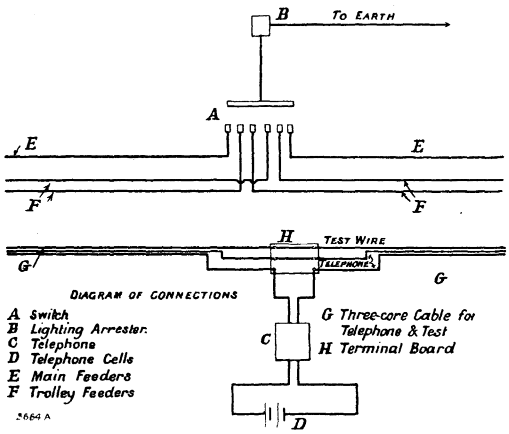


FIG. 387. FEEDER PILLAR CONNECTIONS.

great hydraulic pressure. The cable, thus formed, is yarned and thoroughly dressed with a bitumen compound which saturates the yarn and fastens it to the lead sheath. On this yarn bedding two steel tapes are wound.

Roadways are liable to be disturbed by the gas, water, and sewer excavations, and the men so engaged are careless in the extreme, and when they come across a cable, as often as not do their best to damage it before they find out what they have got to deal with.

The extensions at Bristol are being carried out with an armouring of lock coil segments. The cable itself has a strand of high conductivity wires, insulated by bitumenised fibre, and lead sheathed as before. A bedding of yarn is put on the lead, and on this an armouring, consisting of a considerable number of specially shaped segments, is wound on in such a way that each segment will inter-lock with its neighbour, and

that, when the whole of them are in position and form a ring round the cable, they inter-lock with each other, absolutely making an arch over the cable and rendering it exceedingly difficult to pierce the armouring or to displace the segments. Fig. 386 shows the general arrangement of this sort of cable. This is an adaptation of the well-known lock-coil rope which is so largely used in collieries. It has been found that a willing navvy can have a good half-dozen blows at the cable, hitting it fairly within a few inches of the one place, without causing any injury whatever to the core.

Two complete trolley wires run from end to end of the line, for supplying cars running in opposite directions. They are of hard-drawn copper 0.32 in. in diameter, and are divided by section insulators about every half mile, where the two ends are brought to the switchboxes, and joined to the feeders through the switches. Ætna insulation is used throughout. There are overhead points and crossings at the ends of the line, and at the branch to the power station; and also overhead conductors above the tracks in the station, so as to enable the movement of the cars to be entirely by electricity.

Although this line has existed for some time as a horse-car line as far as St. George's Church, just past the power station, the rails were not considered heavy enough for the new traffic; so that it was decided to lay new rails throughout. The section adopted weighs 76 lb. per yard, and has unusually heavy fishplates. The groove for the wheel is an inch wide and $\frac{7}{8}$ in. deep. No cross-sleepers are used, but the rails are bedded on concrete 6 in. thick, extending the full width of the tramway. They are connected by four cross-ties to each 30-ft. length. These ties are flat steel bars, 2 in. by $\frac{3}{8}$ in., with two nuts at each end, bolted through the web of the rail. The whole track is bonded with "Chicago" bonds, two 3/0 bonds being used at each joint.

There are 22 motor cars (see Fig. 388), each sufficiently powerful to draw an ordinary car after it. They have been made by Messrs. Milnes and Co., the trucks being of the "Peckham" cantilever standard type. The platforms are longer than is the custom with horse cars, so as to allow the motor-man to stand in front of the ladder. Each car is fitted with a hand-brake and a short-circuiting switch on each platform, so that the motors may be used as brakes. The cars will seat 18 persons inside and 26 on the roof; the length inside the body is 12 ft. 9 in., and that over the platforms is 24 ft. The line is 4 ft. $8\frac{1}{2}$ in. gauge, and the length of wheel base is 5 ft. 6 in. The top of the roof is 9 ft. 6 in. from the rail level, and the trolley-post is

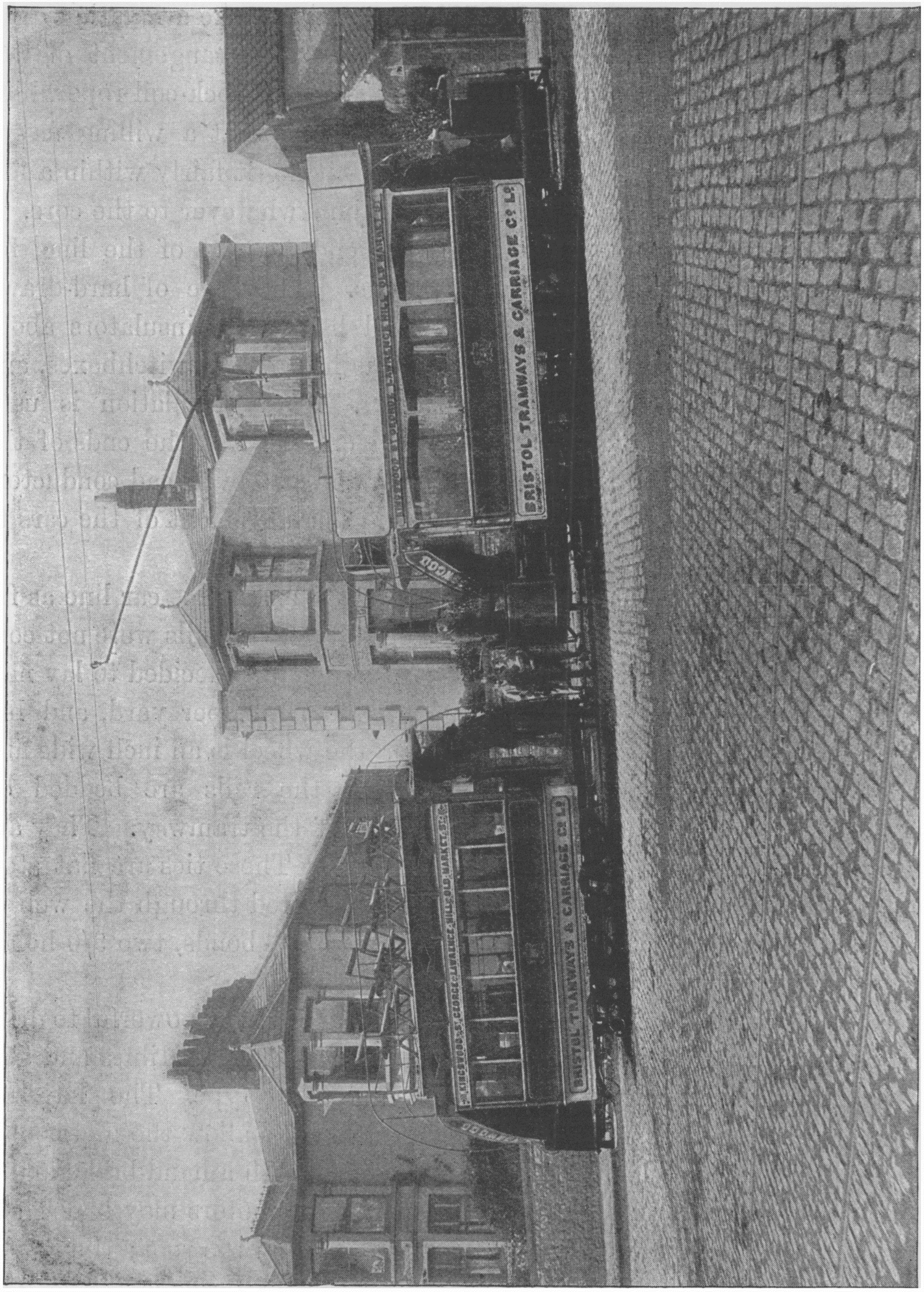


Fig. 388. Motor and Trailer Car, St. George. On grade of 1.15.

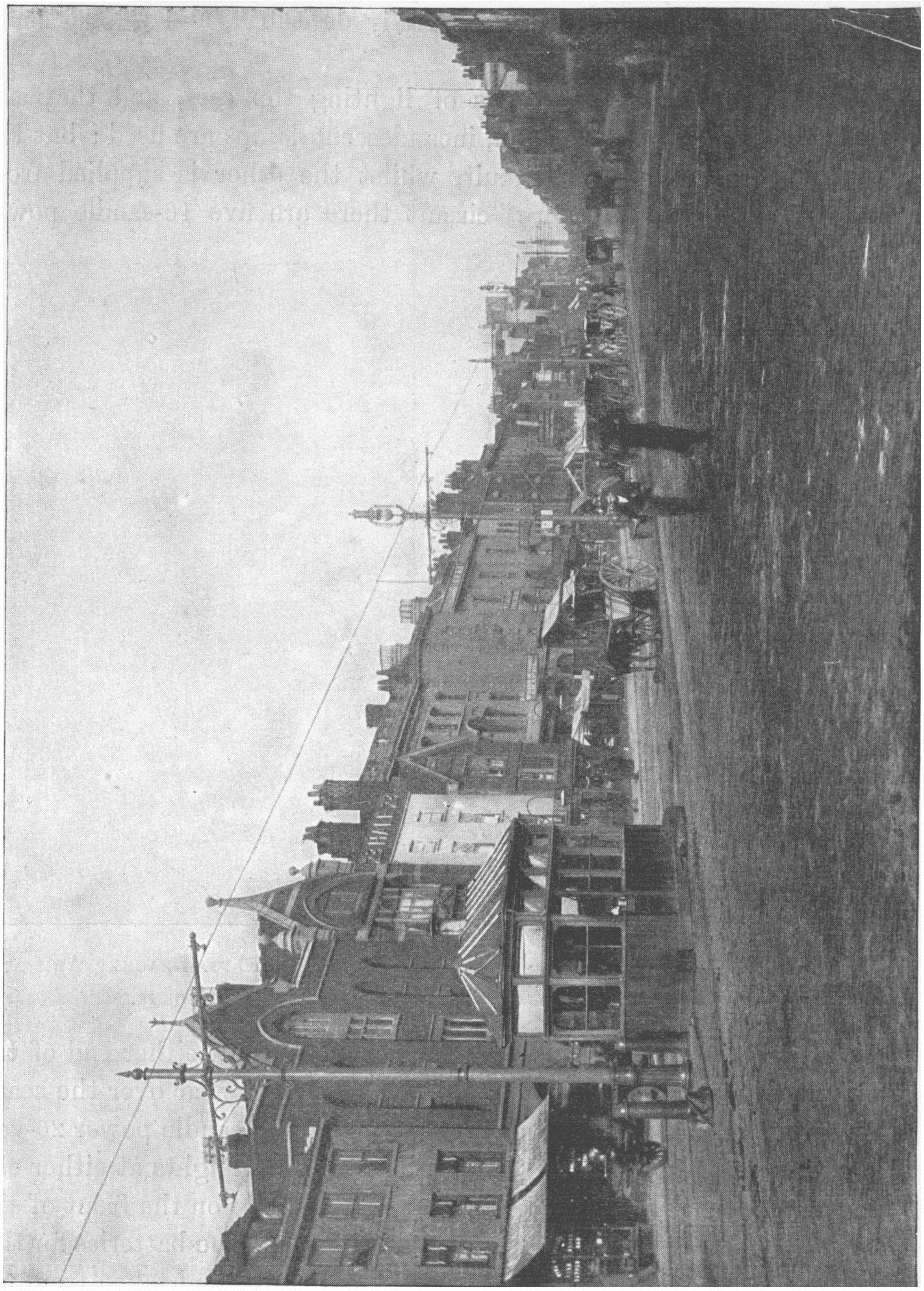


Fig. 389. Centre Pole Construction and Combined Arc Lighting, Old Market Street.

5 ft. 6 in. high; so that the total height of the top of the post above the rails is 15 ft. 6 in. The trolley-post is in the middle of the car on one side; the trolley itself is of the side-pole type already described, and was specially designed for this line.

There are two separate systems of lighting the cars, and they are employed simultaneously. In both, incandescent lamps are used; but the one system is from the main circuit, whilst the other is supplied from accumulators. In the "line wire" circuit there are five 16-candle power

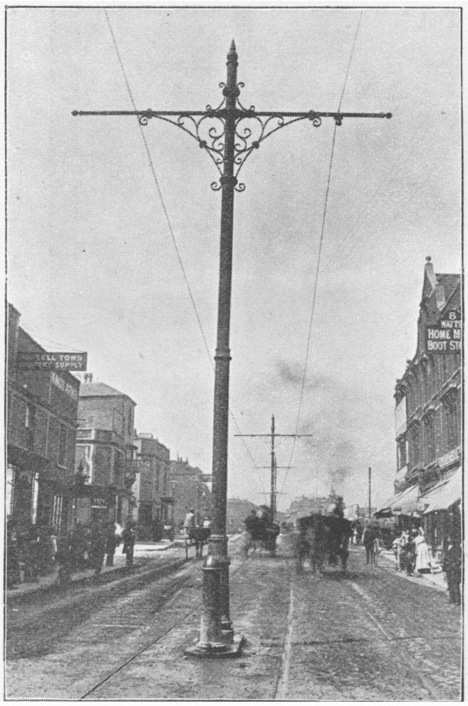


Fig. 390. Centre Pole Construction, Laurence Hill.

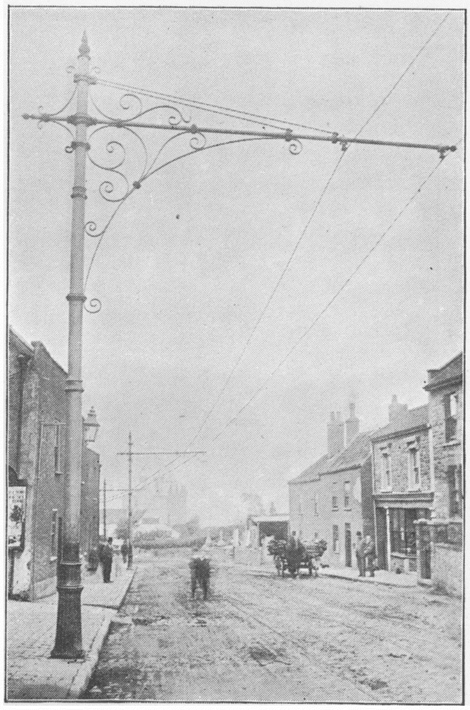


Fig. 391. 16-ft. Bracket Arm at St. George.

lamps. One light is fixed in a coloured bull's-eye lamp at either end of the car, and the three remaining ones are on the sides of the car over the seats. The accumulator lighting consists of two 32 and one 8-candle power 20-volt lamps. The two 32-candle power lamps are in the head lights at either end of the car on the hood over the driver, but only the one on the front of the car is lit. The 8-candle power lamp is inside the car. The batteries for this lighting, when charged, are pushed on to a small truck, and taken from the accumulator room to the cars. There is a space for a 5-cell battery at either end of each car; they are pushed in from the outside, and the connection is

made by means of an automatic spring contact at the back. Each pair of storage batteries will suffice to keep the lamps which depend on it alight for eight hours.. Figs. 389 to 391 give a good idea of the line construction. In Old Market Street centre-pole construction, as shown in Fig. 389, is used, the Corporation arc lights being carried by alternate poles. Fig. 392 shows the first car which was run on the line going through Kingswood.

On the last August Bank Holiday, twelve motor and trailer cars carried over 30,000 passengers.

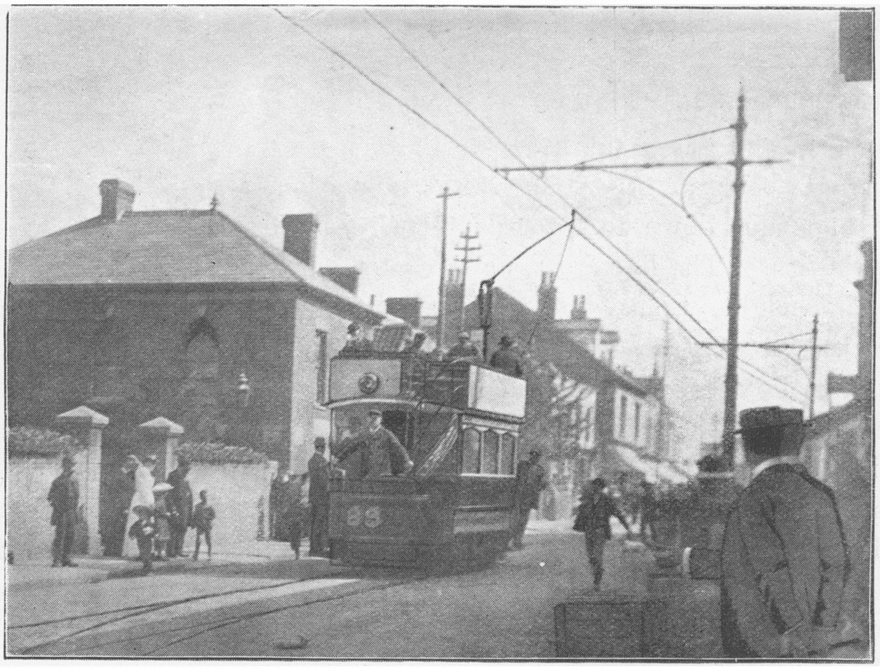


Fig. 392. First Car running through Kingswood.

The Douglas Southern Electric Tramway.—The opening of the Douglas Southern Electric Tramway took place in July, 1896. The length of the line at present constructed is $2\frac{3}{4}$ miles. The gauge is 4 ft. $8\frac{1}{2}$ in., the rails are of steel, 65 lb. to the yard; the sleepers are also of steel, and, with the fastenings, weigh 55 lb. each. Chicago rail bonds are used. At present it is a single line, with eight loops. One of the features of the line is that there is hardly a straight line in it. There is not a level spot on the whole road, and the worst gradient is 1 in 16. There are three bridges of 120 ft., 240 ft., and 110 ft. in length respectively. The trolley-wires are carried on steel poles with brackets. The cars are open, and have garden

seats on the top; they are constructed to carry seventy-eight passengers. A special side trolley, designed by Mr. R. W. Blackwell, is used on this line with great success. The whole of the work was carried out by the General Traction Company, under the supervision of Mr. J. E. Winslow.

THE DOUGLAS AND LAXEY ELECTRIC TRAMWAY.—The Douglas and Laxey Electric Tramway was opened at the end of July, 1894.

The tramway has been specially designed for pleasure purposes, but the inhabitants along the route obtain for the first time all the advantages and conveniences that a local railway would provide. The only means of communication hitherto existing between Douglas and Laxey was by coach or by boat.

The line extends from Portevada, at the end of the Douglas promenade, and rises up a steep gradient, averaging 1 in 24, up to Lagbirragh, being at this point 258 ft. above the sea; the line then turns inland and runs down to Groudle Glen, descending to a level of 128 ft. above the sea. The line crosses a stream by means of a three-arch bridge 60 ft. in height, then climbs the ascent towards the second half-way house, the average grade being 1 in 27, then the public highway from Douglas to Laxey is crossed, and here the highest point of the line, 337 ft. above the sea level, is attained. The total length of the line is 36,435 ft., or a little under seven miles. The permanent way is double throughout, and is of 3 ft. gauge; the width of the cars is a little over 6 ft.

The whole of the electrical plant, boilers, engines, trams, and rolling stock have been supplied and equipped by Messrs. Mather and Platt, to the designs of Dr. Edward Hopkinson.

There are two power stations, one at Portevada, Douglas, at one extremity of the line, and the other at Laxey, the opposite end. The former station is equipped with three Lancashire boilers, 20 ft. long and 6 ft. in diameter, which work at a steam pressure of 120 lb. There are three compound side-by-side vertical engines with high-pressure cylinders 10 in. in diameter, and low-pressure cylinders 20 in. in diameter, the stroke being 8 in. Each engine indicates 100 horse-power, and is fitted with special adjustable governor and heavy flywheel. They work on to a separate condenser, and also to a bye-pass for the exhaust to the chimney. The steam pipes are duplicated throughout, from the boilers to the engine cylinders, as well as to the donkey pump and injector. The condensing water is obtained from a large underground tank, made by building a concrete wall across the creek filled with shingle.

There is room in the engine-house for two more engines. There are two dynamos of the "Manchester" type, and one machine of the "Mather and Platt" type. Each machine has an output of 500 volts and 100 amperes, and is driven by link belts with jockey pulleys. The dynamos are connected to the switchboard, and so arranged that any of the dynamos can be connected to either the feeder cable or the working conductor.

Each machine has a Kelvin electrostatic voltmeter and amperemeter on its circuit. There is also a subsidiary switchboard for connecting independently from the rails to the earth plates, so that any current returned through the earth can be easily measured. The carriage shed adjoins the dynamo-house.

The station at Laxey is in most respects similar to the one at Douglas. There are only two boilers and two engines, which drive "Mather and Platt" dynamos of the same output as the ones at Douglas.

The feature about the Douglas and Laxey line of most interest is the use that is made of accumulators. At Groudle, which is distant some $2\frac{1}{2}$ miles from Douglas, the accumulator station is placed. There are 240 cells of the Chloride type. The battery consists of 120 unprotected cells and 120 protected cells with teak and asbestos separators. It is capable of being discharged at the rate of 140 amperes at 500 volts for three hours, or 90 amperes for six hours, or 70 amperes for nine hours. It could also in an emergency discharge at 300 amperes, that is, 200 horse-power, for about 45 minutes without detriment to the plates. The battery is usually connected in parallel with the two generating stations on to the line, and charges or discharges according to the requirements of the traffic. It can be brought up to the full charge at any time, by a motor generator which is placed in the accumulator station.

The trolley wire consists of high conductivity copper wires, No. 0, B. W. G., suspended from short poles at a height of about 16 ft. above the rail level, by means of the well-known "Ætna" insulators. The poles, fixed midway between the two tracks, have cross-arms carrying a conductor on either side over the centre of the track. The working conductor is fed from an underground feeder cable. This is a lead-covered steel-armoured cable, 37/14 S. W. G., extending from the generating station at Douglas to the Laxey Terminus, and this terminus is again connected with the Snaefell Mountain Electric Railway, which has been acquired by the Company; so that the Company now has a system of 24 miles of line, all

in electrical connection. Boxes are fixed at suitable points of the line to cut out any section, or to connect the feeder, as may be required. The return is by the rails, which are bonded.

The current is taken from the conductor by collectors consisting of two rigid bars carried above the roof of the car.

There are 13 motor cars and 13 open trailing cars with light roofs. The motor cars have longitudinal seats, and seat comfortably 38 passengers; the trailers have transverse seats, and carry 48 people. All the cars are fitted with powerful brakes controlled from either end; there is also an emergency brake available in case of accident to the main brake. This is automatic in its action, and if a trailer, when going up a gradient, should part from the motor car, it will instantly be brought to a standstill.

There are two motors on each car, with helical steel single reduction gear. The motors are designed together to give 3,000 lb. tractive force at the periphery of the wheels. The regulating and reversing switches are fixed at each end of the car, the resistance frames being carried underneath the bogies.

During the year 1895, the number of passengers carried on the Douglas line was 485,267—as many as 10,477 passengers being carried in a single day. The mileage run during the year was 104,552. The traffic is at the maximum during the month of August; the number carried in that month was 169,592. Throughout the winter there is considerable local traffic, which is rapidly developing, in addition to goods traffic.

A portion of the new roadway over which the cars travel is lighted by arc lights, the lamps being placed on the top of the poles carrying the conductors.

Coventry Electric Tramways.—The Coventry Electric Tramways were opened for traffic at the beginning of this year.

The tramway commences outside the railway station, and extends to Bedworth, a distance of six miles, the generating station being about midway. The overhead line work has been executed in three different ways. In the wider streets of the city very neat double-bracket arm poles have been erected; the design of these is clearly seen from Fig. 393, which gives a view of Broadgate. In the narrow streets span wires have been attached by means of rosettes to the houses, and the trolley wire is hung from this. In other parts of the town, span wire construction and side poles have been adopted.

The track is single throughout, and there are approximately 27 turn-outs along its whole length.

The line is divided into half-mile sections. Switchboxes placed in the base of the standards enable each section of the line to be disconnected from the rest of the system. To facilitate the location of the line switches, each post containing one is painted white in the middle.

Outside the town the feeders are carried on side posts, but inside the

FIG. 393. BROADGATE, COVENTRY.

city limits they are underground. The trolley-wire is of hard-drawn copper wire, supported by "Ætna" insulators.

The track consists of a single line throughout, and is of 3 ft. 6 in. gauge. The rails are double bonded with Chicago bonds.

The rolling-stock for the complete length of line consists of 10 cars. The cars are slightly over 20 ft. in length, with a wheel base of 6 ft. In all cases the "Peckham" cantilever truck is used. Two motors are employed on each car (see Fig. 394, representing the motor truck).

The motors are of four-pole Westinghouse type, supported on the truck by means of parallel side-bars, and capable of developing 25 horse-

power. They are adequately protected from mechanical injury by casing, and are readily inspected through a trap door in the floor of the car. Single reduction spur gear is employed, the gear being of cut steel, and working in oil.

The steam plant is arranged on a lower level than the engine room. Two Babcock and Wilcox boilers are used, each capable of developing 100 horse-power. These boilers are fed by Babcock-Wilcox automatic

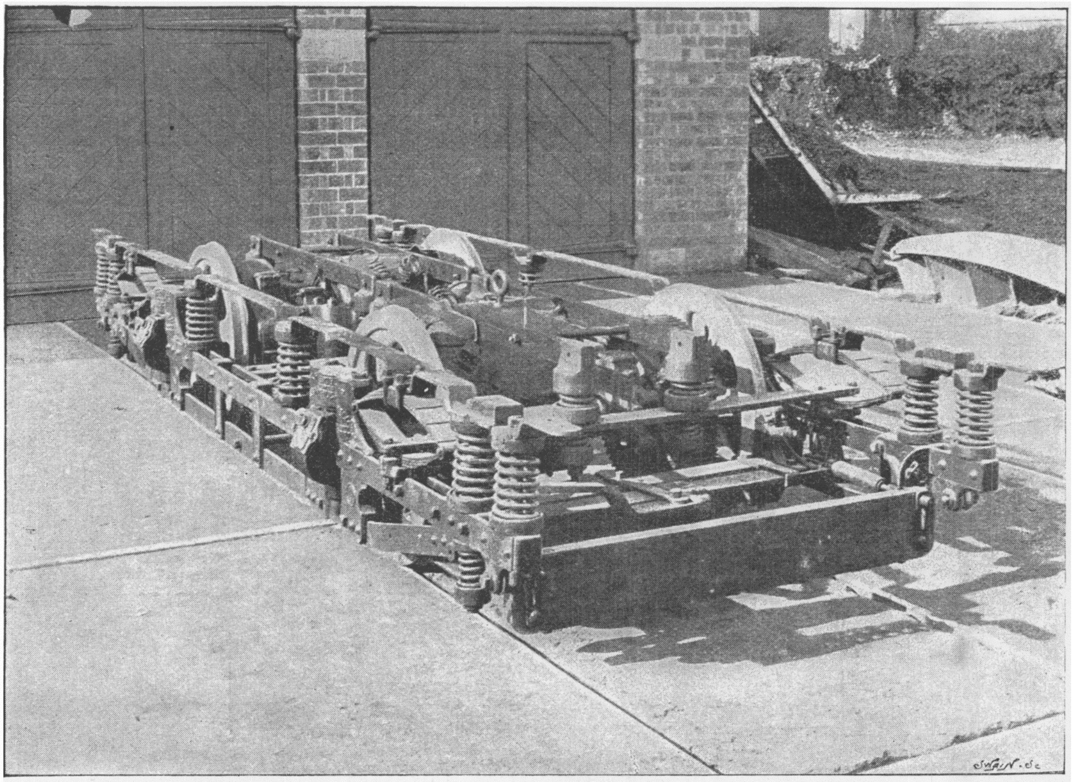


FIG. 394. "PECKHAM" MOTOR TRUCK, COVENTRY.

stokers. Feed water is obtained from an adjacent canal. Power for driving the stokers is obtained from a Sturtevant vertical engine in the engine room. The generating plant is in a room, half of which is a workshop provided with machine tools, and the other half occupied by the electrical plant. The generating machinery consists of two Westinghouse railway generators, driven by horizontal engines. The engines are non-condensing single cylinder type, the cylinder being 13 in. in diameter, with a 13 in. stroke. They run at 240 revolutions per minute, and will indicate 130 horse-power each.

The dynamos are driven by means of leather belting, and have each an output of 100 kilowatts. They are of the Westinghouse four-pole type, and are over-compounded. The armatures are ironclad, and built up of heavy copper bars, the core being of special laminated steel,

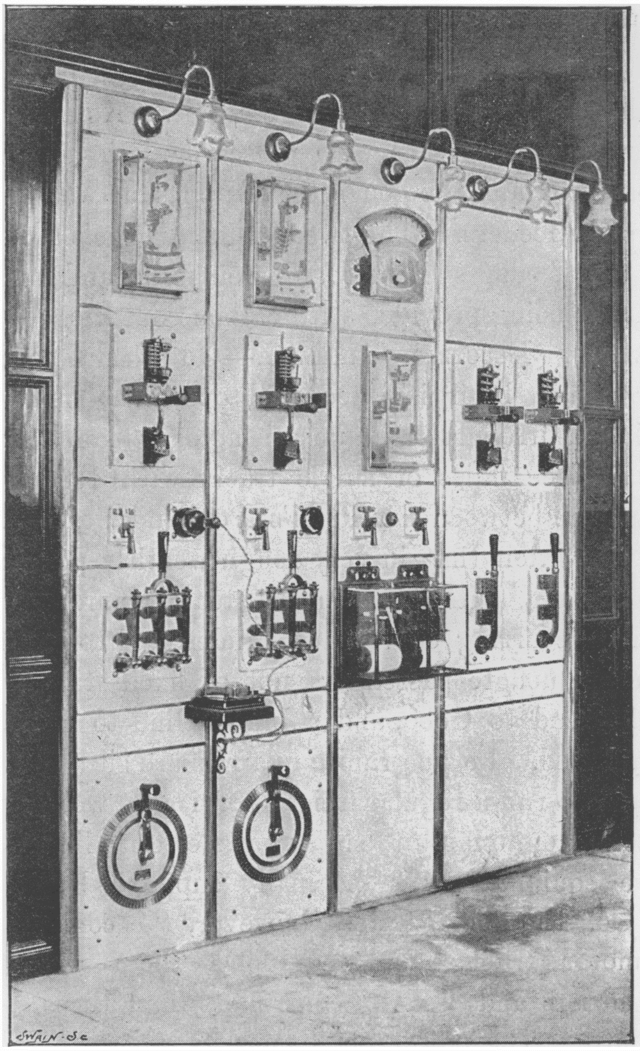


FIG. 395. COVENTRY SWITCHBOARD.

similar to the pole pieces. Carbon brushes are used, and as the brush-holders are fixed on a ring provided with handles, the simultaneous adjustment of the brushes is rendered easy. Six pilot lamps are placed on the top of each generator, and serve to indicate the condition of the line.

In a corner of the engine room is a Berryman feed-water heater, through which the exhaust steam passes on its way to the atmosphere. The whole of the piping is lagged with magnesia covering.

A small dynamo, driven by a Sturtevant engine, provides for the lighting of the station and the car sheds.

The switchboard is of white marble, divided into four panels (Fig 395). There is a board set apart for instruments designed to make tests in accordance with the Board of Trade regulations. As at Bristol, there has been no difficulty in complying with these regulations. The right-hand panel of the board contains the generator switches, as well as two automatic circuit breakers for feeders. The two left-hand panels are for the feeders, and on these are feeder switches, amperemeters, and automatic circuit breakers, the latter being provided with carbon contacts.

THE GUERNSEY ELECTRIC TRAMWAY.—On the Guernsey Tramway electric motors have been in successful operation since March, 1892, having replaced an irregular and unsatisfactory steam service. The line now consists of three miles of single track, with turnouts, and closely follows the coast-line between St. Peter's Port and St. Sampson's, occupying so exposed a position that in very rough weather portions of the track are washed by the sea. Its failure as a steam tramway was largely due to the constantly recurring curves and grades, and to the fact that stops are made to accommodate passengers, not at fixed stations. A four-mile extension of the road to Cobo, and a branch line to Bordeaux Harbour, are now contemplated. Large granite quarries are situated at these points, and it is proposed to run a regular freight service, as well as passenger cars, to bring the stone from quarry to ship by the electric line.

The entire equipment was originally supplied by Messrs. Siemens Brothers and Co., Limited. Lately, however, the company have adopted "Peckham" motor trucks, and equipped them with two standard "G. E. 800" motors and "K 2" controllers, and these have now been made the standard. The power plant consists of two Marshall compound engines (each 25 nominal horse-power), combined with locomotive boilers, this type having been chosen primarily on account of ease in transportation and simplicity of erection. Each engine has a Worthington pump, Friedman injector, and feed-water heater. The high-pressure cylinders are fitted with Hartnell expansion gear, which acts through a link and die, on to an expansion cut-off slide valve at the back of the main slide valve. This gear has kept the speed constant within five

per cent., even under the great variations in load which are unavoidable in tramway work. The diameters of the high and low pressure cylinders are 10 in. and 16 in. respectively, while the stroke is 18 in.; the normal revolutions per minute are 120, with a working pressure of 140 lb. The fly-wheels have a diameter of 8 ft., and a weight of 42 cwt. 3 qr. It may incidentally be mentioned that excellent feed-water is obtained by mixing the rain-water from the buildings with that of a spring on the premises, an abandoned quarry being utilised as a reservoir.

A Siemens compound-wound central station dynamo, capable of giving 100 amperes at a pressure of 500 volts, is belt-driven by each engine, at a speed of 350 revolutions per minute. A Schaffer and Budenberg tacheometer can be connected at will to either dynamo. A single engine and dynamo suffices for ordinary traffic. The sets work alternate fortnights. The average daily run is $17\frac{1}{2}$ hours without stop.

The station buildings are of stone and corrugated iron, the power house, workshop, car and coal shed being conveniently connected together. Three tracks run into the car shed, and each has a pit 46 in. by 54 in. its entire length, affording easy access to the driving mechanism and running gear. All repairs are made at the station.

The rolling stock consists of nine motor cars and two trailers. Four of the motor cars have "Peckham" bogie trucks and double motor equipments, and seat 68 persons each. The others have "Peckham" four-wheel motor trucks and double motors, and seat 52 passengers each. Each motor is of 25 nominal horse-power.

Connection between the overhead conductor and the car is made in the ordinary way by a trolley pole and wheel. The only peculiarity is that the trolley head is connected to the hollow steel pole by means of a piece of ash, being thus insulated from the pole and its base. The insulated cable carrying the current to the motors passes through the tubular pole. The trolley itself pivots on a socket head furnished with ball bearings, and the upright supporting these bearings is screwed into a cast-iron bracket bolted to the side and top of the car. The usual upward pressure of the trolley against the wire is about 15 lb.

The trolley wire along the line is supported about 2 ft. outside the track by light bracket-arm poles. The trolley wire itself is of 9-millimetre hard-drawn copper. The spans vary between 40 and 48 yards. The whole overhead construction is very light and inconspicuous, and if anything rather too light. It is now being strengthened throughout.

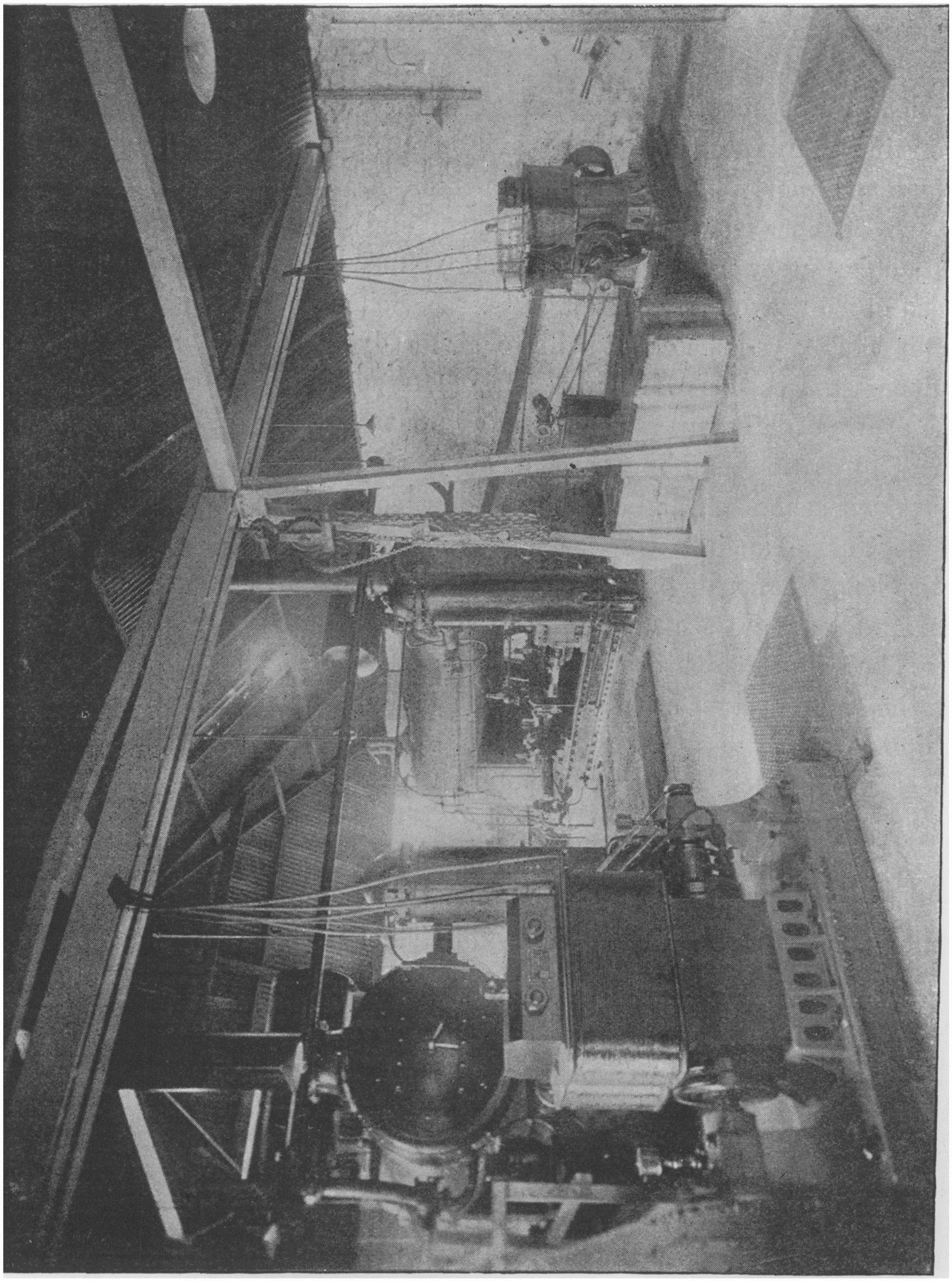


Fig. 396. Power Station, Guernsey Railway.

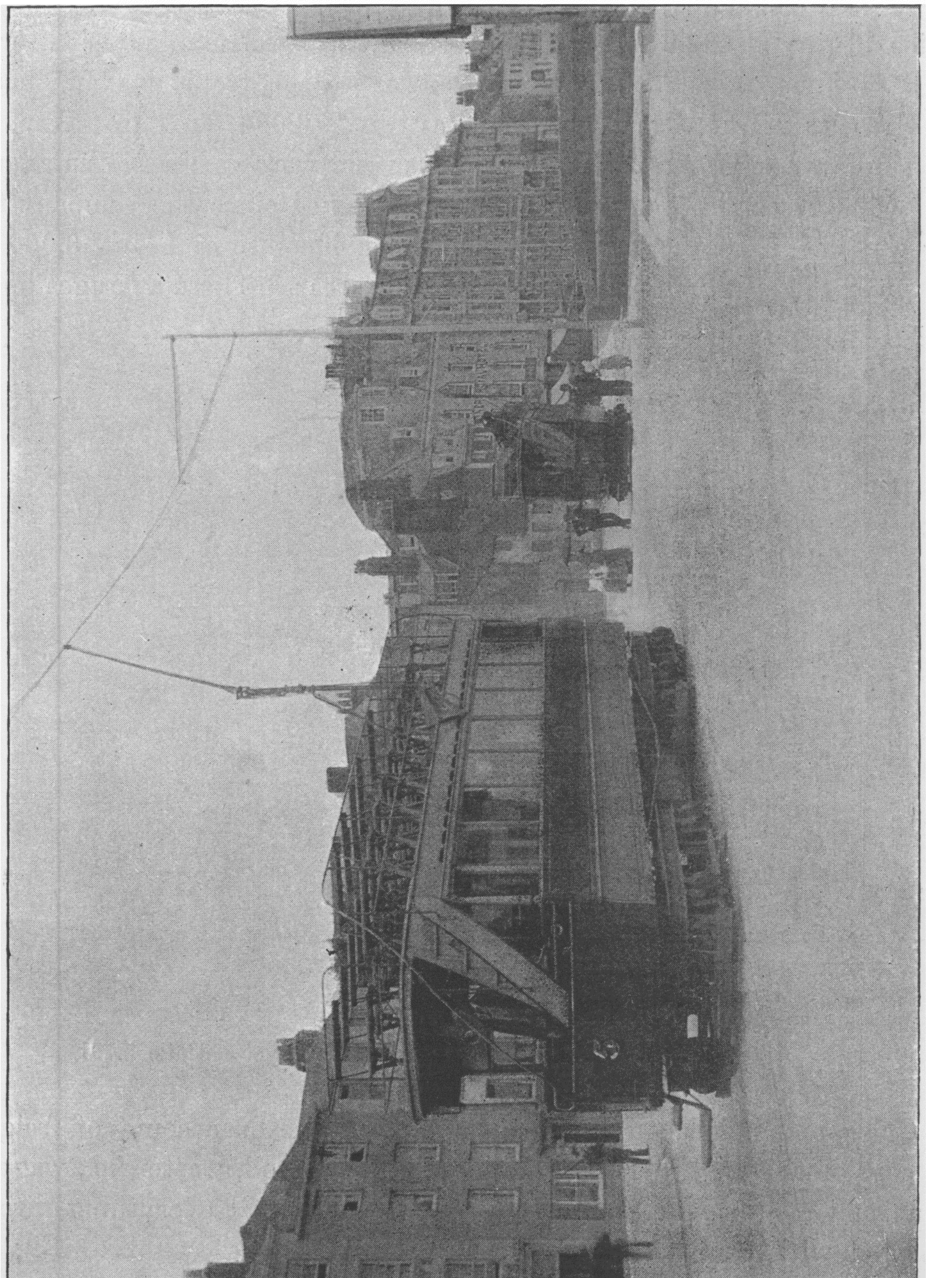


Fig. 397. St. Peter Port, Guernsey, Electric Railway.

The permanent way is very old, and is about to be replaced. The metals are partly Vignoles and partly old-style grooved tramway rail.

A workman's car starts every morning at six o'clock. Regular service begins at 7.25 a.m. and is kept up at twelve minutes' intervals till 10.30 p.m. On Saturdays (market days) the traffic is very heavy, and the cars run until 11. On holidays over 6,000 fares are taken, and in a single week in August, 27,162 passengers were carried. An average of 15,000 passengers per week has been attained since the company took over the line from the contractors, being an increase of nearly 3,000 per week over the same period of the preceding year. These averages do not include holiday traffic.

TABLE XCIII.—Giving Statistics of Working and Maintenance for the Quarter ending December 31st, 1893.

Average number of cars running	5
,, daily mileage per car	70
,, speed per hour in miles	7.2
,, pounds of coal consumed per car-mile	8
,, number of passengers per car-mile	7
,, ,, ,, ,, (holidays)	13

Costs per Car-Mile.	*d.*
Salaries	0.652
Wages and repairs in power house	0.636
Wages of drivers and conductors	1.716
Workshop repairs and car cleaning	1·243
Maintenance of permanent way and electrical conductors ...	0.312
Coal	0.747
Oil and sundries in power house	0.234
,, ,, repair shop and car shed	0.181
Printing and stationery	0.070
Total per car-mile	5.791

Coals, and indeed all materials, are expensive on account of freights. The cost of running, strictly speaking, viz.—coal, oil, waste, &c., wages of engine and car drivers, conductors, car cleaners, and everything directly connected with car service—does not exceed 4d. per car-mile. Fig. 396 gives a view of the inside of the power-house, and Fig. 397 of the end of the line at St. Peter Port.

The City and South London Electric Railway.—The original Act for the City and Southwark Subway, as it was then called, was obtained in

1884. The promoters sought powers to build a double line from King William Street, E.C., to the Elephant and Castle, pledging themselves not to make use of steam locomotives for haulage. In 1887 they obtained an extension to the Swan at Stockwell, and supplementary Acts permitted them to carry the line forward to Clapham Common and backward as far as Islington, when they see fit. The last Act also changes the name of the undertaking to the City and South London Railway Company. The total distance from King William Street to Stockwell is about $3\frac{1}{4}$ miles, and in it there are four intermediate stations, the greatest distance between any two being three-quarters of a mile, while the average distance is about three-fifths of a mile. The entire length is underground, the rails never being less than 40 ft. below the surface, and in some cases, as that of the crossing of the Thames, the depth is much greater, being as much as 70 ft. The up and down lines are carried in distinct tunnels, running generally side by side, but one a few feet higher than the other to enable the passengers from one train to pass under the platforms of the other, and thus readily reach the lifts. In Swan Lane the width of 13 ft. was too small to allow of the two tunnels being laid side by side, and one was placed over the other to avoid all interference with the foundations of the adjoining buildings.

The shortest radius is 140 ft. A severe gradient is met on the north bank of the river; the up line rises at 1 in 30 and the down line drops at 1 in 15. There are also short gradients at each side of each of the intermediate stations. Near the southern end of the line there is a short tunnel rising at a gradient of 1 in $3\frac{1}{2}$ into the depôt. By this the trains are brought up into the sheds at night, while it forms a general avenue of communication for hydraulic pipes, electric conductors, and the like. The traffic on this incline is worked by a steel rope and a stationary winding engine, as indicated in the plan of the depôt, Fig. 398.

The tunnels are formed of cast iron from end to end, except at the parts where they are enlarged for the stations. They are 10 ft. in diameter from the City to the Elephant and Castle, and 10 ft. 6 in. for the remainder of the distance. The tubes are formed of rings 1 ft. 7 in. long, and each ring is seven pieces, six equal segments, and a short key-piece with parallel ends. The flanges are $3\frac{1}{2}$ in. deep by $1\frac{1}{4}$ in. thick, and are bolted together by $\frac{3}{4}$-in. bolts. The circumferential joints are made by tarred rope, and the longitudinal joints by pine strips; 30,000 tons of plates, and 1,500,000 bolts have been used in the structure. The method of driving the tunnels was new, and was effected by aid of a Greathead shield. It is

a short cylinder fitting over the end of a tunnel, as a cap fits over the end of a telescope. It has a cutting edge in advance, and is forced forward by hydraulic jacks, which take their abutment on the piece of tunnel already complete. A door in the end of the shield permits of the soil being brought through and loaded into wagons.

This method of tunnelling has proved most successful. It was carried out at such speed that at one time the contractors, working at six faces, accomplished 100 ft. a day. The average at each face was 13 ft. 6 in. per day. Whenever the shield was used no settlement took place, the tunnel

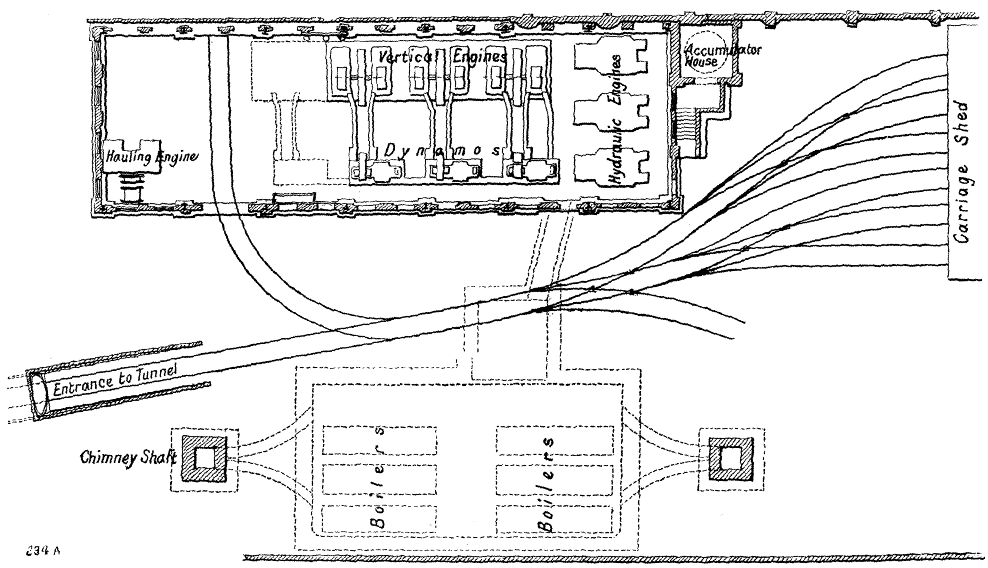


FIG. 398. PLAN OF POWER HOUSE OF CITY AND SOUTH LONDON RAILWAY.

actually filling the space cut for its reception, and making no disturbance in the adjacent soil.

At each station there has been constructed a lift well, 25 ft. in diameter, lined with iron rings like the tunnel. In this there work two cages, semicircular in plan, each capable of accommodating fifty passengers, that is, half a trainful. Power to work the lift is supplied by water at 1,200 lb. pressure, pumped from the depôt at Stockwell through a 7-in. main, which is gradually reduced in diameter to $3\frac{1}{4}$ in. The water is employed in lift cylinders, $6\frac{1}{2}$ in. in diameter. The cylinder is fixed vertically to the side of the well, and obtains a treble purchase with sheaves and wire ropes. Four of these ropes, each with a breaking strain of 55 tons, or 210 tons in all, are attached to the cage which will

carry a load of $3\frac{1}{4}$ tons only. There are also two wire ropes connecting the cage to the counter-weights, and thus the chances of a breakdown are infinitesimal. The lifts are fed by three 100 horse-power compound hydraulic engines supplied with steam at 95 lb. pressure. The cylinders are $15\frac{1}{2}$ in. and $29\frac{3}{4}$ in. in diameter, with a stroke of 20 in., and the pumps have each a 3.9 in. piston, with a plunger of half the area. The waste water is all returned to the depôt, and is used again and again. The quantity under pressure is stored in a large accumulator, 17 in. in diameter, with 17 ft. stroke, and there is a second accumulator, $9\frac{1}{2}$ in. in diameter and 27 ft. stroke, about the middle of the line, to reduce the velocity of flow through the pipes.

Each train will accommodate 100 passengers. It consists of an electric locomotive and three carriages, the whole weighing from 30 to 40 tons. The carriages are open from end to end, and have two longitudinal seats like a tramcar. They are, however, considerably wider than a car, so that there is ample space for the movement of passengers. The height is 7 ft. from floor to roof. The doors at the ends give on to platforms, which are guarded at each side by folding gates. These gates can expand and contract as the cars go round the curves. Each car is carried on two four-wheel trucks, and each wheel is fitted with the Westinghouse brake. The compressing pumps for the air, like all the other machinery, are situated in the depôt, and not on the locomotives. These latter carry reservoirs for air, of a capacity sufficient for fifty stoppages. As ordinarily there will only be a dozen stoppages on a double journey, there is an ample margin. The reservoir is refilled at Stockwell. The tunnels themselves are not lighted. Four incandescent lamps are fitted in each carriage.

Messrs. Mather and Platt, of Manchester, undertook to provide the whole of the electric plant, engines, dynamos, conductors and motors, and to undertake that the haulage of the trains should not exceed a cost of $3\frac{1}{2}$d. per train-mile. A train on the District Railway costs $9\frac{1}{2}$d. for the same work. A contract was made with them in January, 1889, for doing this. This contract provided for the supply of 14 locomotives, to draw trains consisting of three carriages accommodating 100 passengers, and weighing $4\frac{1}{4}$ tons each, and the generating plant was to be sufficient for working a service of 20 trains per hour, the contractors undertaking to work the line for a term of two years, or to guarantee the cost of haulage for a similar period, at the option of the company. In October, 1889, an electric locomotive was run experimentally on a short section of the line.

The works were formally opened on the 4th of November, 1890, and on the 18th of December the line was opened for public traffic.

The electric locomotive, Figs. 399 and 400, weighs about 10 tons, and is carried on two axles on a short wheel base. On each axle there is built the armature of an electric motor. The two axles are quite independent, and there is no gearing of any kind on the locomotive. The armatures are series wound; their speed varies, of course, with that of the train, but at 15 miles an hour is 190 turns a minute. The maximum power which

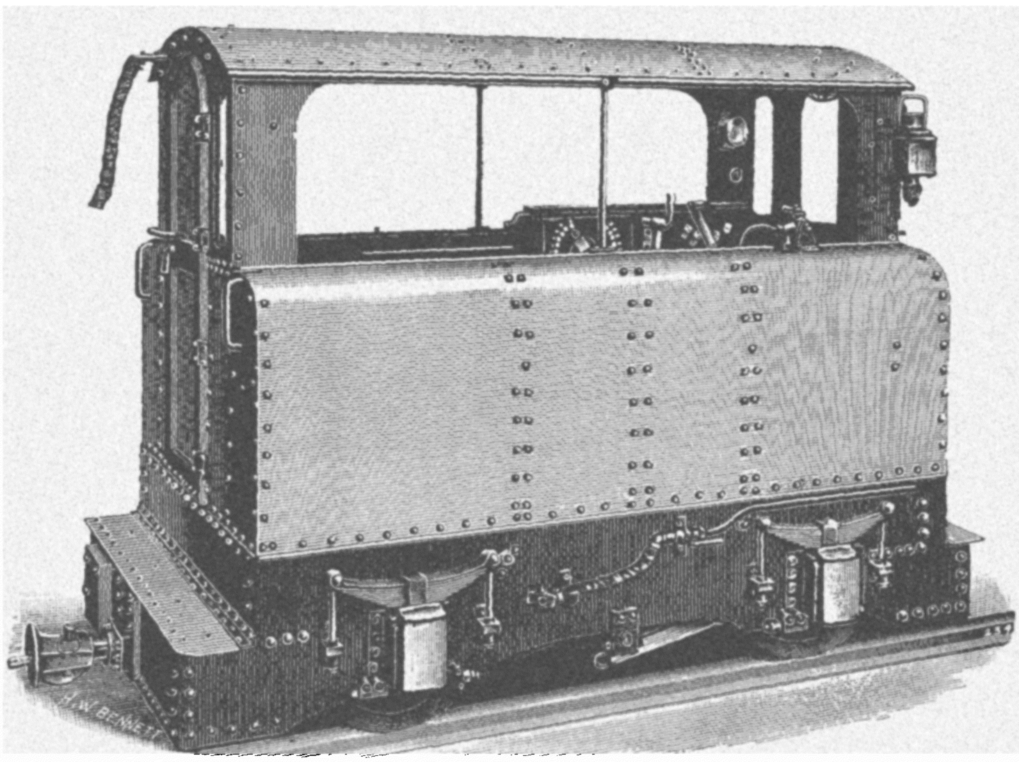


Fig. 399. City and South London Electric Locomotive.

can be obtained from one of these locomotives is 100 horse-power. The locomotives are designed to run up to 25 or 26 miles an hour, and to make the entire journey of $3\frac{1}{4}$ miles at the rate of 15 miles an hour. Both motors are controlled from a single switch handle, which gradually removes resistance from the main circuit as it is put over. There is a second switch which reverses the motion by reversing the fields. The current is picked up from a centre rail, made of a steel channel, and laid along the track, by three heavy slippers which slide on the rail and can adapt themselves to any unevenness. The rails themselves serve for the

return conductor. There are four copper feeding mains along the track, connected to the steel channel at different points to maintain an even potential as far as possible of 500 volts. These cables each contain sixty-one wires of 14 Birmingham wire gauge, and are insulated with Fowler-Waring material, covered with lead sheathing. The working conductor is of steel of high conductivity, specially rolled for the purpose. The bars are fished and connected by copper strips. They are carried on glass insulators.

The entire current for the trains is generated at the depôt (Fig. 401).

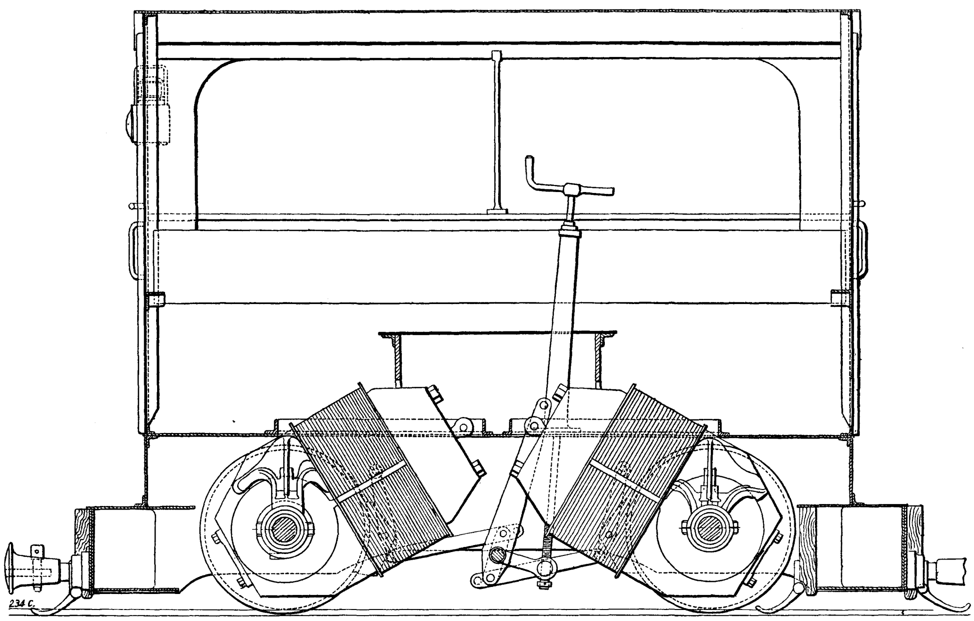


FIG. 400. SECTION SHOWING ARRANGEMENT OF MOTORS ON LOCOMOTIVE, CITY AND SOUTH LONDON RAILWAY.

There are three Edison-Hopkinson dynamos, each driven by a belt from compound inverted engines of 375 indicated horse-power, built by Messrs. John Fowler and Co., of Leeds. They have cylinders 17 in. and 27 in. in diameter respectively, with a stroke of 27 in.; run at 100 revolutions, or 450 ft. per minute. Each cylinder has a separate expansion valve, worked automatically by a block and link under the control of the governor, the cut-off varying from *nil* to $\frac{3}{4}$ stroke. A specially powerful governor of the Wilson-Hartnell type has been provided for this purpose, and is driven by four ropes 1 in. in diameter. Each engine has a flywheel 14 ft. in diameter by 28 in wide, and carries a 26-in link belt. This belt runs over a 2 ft.

10 in. pulley on the dynamo, and is tightened by means of a massive jockey pulley, which causes it to embrace three-quarters of the circumference of the driven pulley. The engines are supplied with steam at 140 lb. pressure, generated in six Lancashire boilers, each 7 ft. in diameter by 28 ft. long. Vicars' self-acting stokers and Livett's flues are used in conjunction with these boilers. The feed water is passed through two large heaters fitted with brass tubes, and receiving all the exhaust steam.

A direct-coupled generator has lately been added, and now forms part of the equipment of the Stockwell power station. It consists of a Siemens

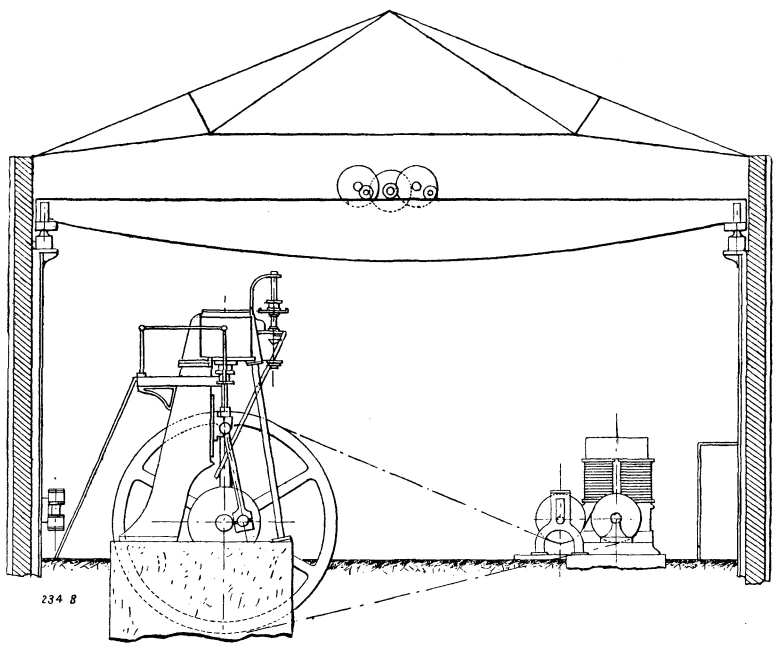


FIG. 401. TRANSVERSE SECTION THROUGH ENGINE ROOM, CITY AND SOUTH LONDON RAILWAY.

compound-wound dynamo, coupled to a two-crank compound non-condensing Willans engine. This plant is required to take a portion of the duty during the evening hours, when it runs in parallel with one of the original Mather and Platt belt-driven generators. It is erected on the floor of the gangway between two of these original sets. The new set has, roughly, half the capacity of the older sets, and normally developes 250 amperes at 500 volts. It runs at a normal speed of 350 revolutions per minute.

The dynamo is of the vertical, under-type, two-pole, single-magnet type, with a drum-wound bar armature. The armature is 21 in. in

diameter, and the pole face is 36 in. The series windings are provided with a hand switch, whereby they may be cut out of circuit.

The engine developes a normal power of 180 B. H. P. when supplied with steam at 130 lb., and running at 350 revolutions per minute. It is built, however, to develope, on occasion and for short intervals, considerably greater power than this; and to this end it is provided with Messrs. Willans and Robinson's ingenious automatic cut-off valve gear. The diameter of the high-pressure cylinders is 14 in., and of the low-pressure cylinders 20 in.; the diameters of the hollow piston rods are 4 in. above the high-pressure piston, and $5\frac{1}{2}$ in. above the low-pressure piston. The stroke is 9 in.

The Edison-Hopkinson generator dynamos are fitted with bar armatures; the weight of each armature is about two tons, and of each complete machine over 17 tons. The commutators are of hard copper insulated with mica. The magnet limbs are exceedingly massive, each limb with its pole-piece being over 4 tons, and the yoke of the machine about 3 tons. The output is 450 amperes at 500 volts, the electrical efficiency being 96 per cent., and the combined efficiency of engine and dynamo, or the ratio of electrical power at the poles of the generator to the indicated power of the engine, 75 per cent. The current is led from each dynamo to the switchboard in the engine-room, and is there distributed to the feeding mains. An automatic cut-out and a resistance provides security against a short circuit in the mains.

From the switchboard the feeder cables are taken into the tunnels, where they are carried on brackets along the sides of the tunnel. All the cables are led through and interrupted at each signal-box. In the signal-boxes are fixed small slate distributing boards, fitted with plugs and fuses, and from these the current is conveyed to the working conductor by means of feeder cables.

The daily tests of the entire system, which include generators, switch-boards, cables, feeders, working conductor, points and crossings, locomotives, and lighting circuits with the full pressure of 500 volts—do not give a leakage current of 1 ampere, or considerably less than 1 horse-power.

The stations and the passages are entirely lined with white tiles, except on the parts monopolised by the inevitable advertisements. These tiles have a bright and cheerful gleam under artificial light.

At each station is a signal cabin provided with a complete set of block instruments of a somewhat modified type. Some of the levers are

electrically locked with the signals, and one of them can only be released ordinarily after the engine has passed over a treadle beyond the signal.

The following figures (Table XCIV.), taken from a paper read by Mr. Alexander Siemens before the British Association may be of interest as regards the power absorbed on this line by the locomotives at various speeds.

TABLE XCIV.—Giving Power Absorbed by Electric Locomotives on the City and South London Railway.

Speed in Miles per Hour.	Electrical Horse-power put into Motor Armature.	Electrical Horse-power put into Motor Magnets.	Total Electrical Horse-power per Motor.	Total Electrical Horse-power per Locomotive.	Brake Horse-power Measured.	Efficiency per cent.
12.25	56.96	2.8	59.76	119.52	110	92
14.77	24.42	1.21	25.63	51.26	47.1	91.87
15.7	21.5	0.86	22.36	44.72	40.2	89.89
17.83	21.85	0.74	22.59	45.18	42.62	94.32
22.73	29.23	0.35	29.58	59.16	54.3	91.79
24.7	19.5	0.2	19.7	39.4	36.6	92.68
30.6	26.27	0.17	26.44	52.88	48.76	92.19

Table XCV. is of great interest, as showing the constant decrease in working expenses which has taken place since the line has been opened. It is based upon the half-yearly returns of the company, and shows the total cost of locomotive power and the train mileage, from which the costs per train mile are deduced. It will be seen that for the half year ending June 30th, 1891, the total cost was 9.1d. per mile, and the running expenses 8.4d. per mile; whilst for the last half-year—January to June, 1896—the total cost has been reduced to 5.79d., and the running expenses to 4.69d. respectively.

The average speed of working on the South London line, including intermediate stoppages, is 11.5 miles per hour, and of actual running between stations 13.5 miles per hour. The maximum speed attained between stations varies from twenty to twenty-five miles per hour. The headway varies from three to four minutes, sixteen or seventeen trains leaving each terminal station in one hour.

Bessbrook and Newry Tramway.—A great interest attaches to this road, owing to the success which it encountered from the beginning, and to its being one of the first roads on the electric system. This line is located in Ireland, and it connects the Newry terminus of the Great Northern Railway to the mills at Newry proper, which is some distance away

from the railway station. The plant was designed and constructed by Dr. Edward Hopkinson.

TABLE XCV.—Giving Working Expenses of City and South London Railway.

Half-year Ending— / Items.	June 30, 1891.			Dec. 31, 1891.			June 30, 1892.			Dec. 31, 1892.			June 30, 1893.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
Salaries, offices, expenses, and superintendence	65	12	0	100	8	4	192	3	4	148	11	8	122	10	0
Running Expenses.															
Wages connected with workiug the generating and locomotive engines	3,408	16	10	3,258	1	9	2,720	8	1	2,788	12	6	2,687	12	7
Fuel	2,054	4	10	1,985	18	6	1,970	19	4	2,172	0	9	1,845	18	9
Water and gas	251	5	6	263	9	6	253	11	0	252	9	9	242	12	
Oil and stores	434	2	1	371	18	1	415	3	4	457	6	11	426	19	2
Repairs and Renewals.															
Wages	150	0	0	26	3	9	205	0	0	240	0	0	252	4	0
Materials	223	2	1	193	13	0	277	17	10	289	3	1	298	4	10
Total	6,587	3	4	6,199	12	11	6,035	2	11	6,348	4	8	5,876	1	10
Total of running expenses only..	6,148	9	3	5,879	7	10	5,360	1	9	5,670	9	11	5,203	3	0
Train mileage	174,435			188,666			188,944			214,417			217,664		
Total cost of locomotive and generating power per train mile	9.1d.			7.8d.			7.7d.			7.1d.			6.48d.		
Cost of running expenses per train mile ..	8.4d.			7.0d.			6.7d.			6.3d.			5.7d.		

Half-year Ending— / Items.	Dec. 31, 1893.			June 30, 1894.			Dec. 30, 1894.			Dec. 31, 1895.			June 30, 1896.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
Salaries, offices, expenses, and superintendence	121	7	7	124	0	5	119	14	3	95	6	9	80	1	11
Running Expenses.															
Wages connected with working the generating and locomotive engines	2,686	5	5	2,641	0	5	2,659	6	3	2,574	6	5	2,440	14	2
Fuel	1,809	10	0	1,862	4	3	1,723	6	5	1,707	12	8	1,603	13	7
Water and gas	191	19	11	182	3	9	176	17	7	60	0	0	67	16	9
Oil and stores	353	16	4	346	1	0	313	18	3	330	12	0	296	13	1
Repairs and Renewals.															
Wages	267	16	0	293	16	0	352	6	0	416	0	0	450	0	0
Materials	383	17	10	444	8	3	446	13	7	523	10	4	507	8	9
Total	5,814	13	1	5,893	14	1	5,792	2	4	5,707	8	2	5,446	8	3
Total of running expenses only..	5,041	11	8	5,031	9	5	4,873	8	6	4,672	11	0	4,408	17	7
Train mlleage	224,101			227,363			230,604			227,350			225,554		
Total cost of locomotive and generating power per train mile	6.22d.			6.22d.			6.03d.			5.92			5.79		
Cost of running expenses per train mile ..	5.4d.			5.31d.			5.07d.			4.93			4.69		

The work was commenced in November, 1884, and the line opened for traffic in October, 1885. It was formally taken over by the company, as having fulfilled the conditions of the contract, in the following April. Since that time it has been in regular daily operation.

The total length of the line is 3 miles, 2.4 chains, and the average gradient 1 in 86, the maximum being 1 in 50. The gauge is 3 ft., the line

is single track, but land has been purchased for doubling it. At each terminus is a loop of 55 ft. radius, so that the cars do not need reversing. The passenger cars are 33 ft. and 21 ft. long, each provided with one motor. The body of the car is carried on two four-wheeled bogies, with a wheel base of 4 ft. 6 in. The motor is carried on the front bogie independently of the car body. Table XCVI. gives the weights of the various parts composing the motor car.

TABLE XCVI.—Giving Weight of Car.

	tons.	cwt.	qrs.
Car body ...	3	6	1
Leading bogie ...	1	17	2
Trailing ,, ...	1	0	0
Dynamo, bed-plate, armature, and accessories ...	2	1	1
Total weight ...	8	5	0

A special feature is that the waggons used on the line can also be used on the ordinary public roads, so avoiding the nuisance of transshipment. The wheels of the waggon are $2\frac{3}{4}$ in. wide, and without flanges. Outside the tramway rails, which are of steel and weigh 41.25 lb. per yard, a second rail is laid weighing 23.75 lb. per yard, with the head $\frac{7}{8}$ in. below that of the heavy rails. The flangeless wheels run upon these rails, the ordinary ones forming the inside guard. The wheels are loose on the axle, the axle itself being carried in a journal. The front part of the waggon rests on a fore-carriage, which can be pinned or left loose as in an ordinary road vehicle. There is a single central coupling arranged to engage in a jaw in the fore-carriage, so as to guide it when not pinned. Shafts are attached to the fore-carriage when the waggon is to be used on the ordinary roads. The weight of the waggon without the shafts is $23\frac{1}{4}$ cwt., and it can carry 2 tons.

The generating machinery is at Millvale, a distance of 68 chains from the Bessbrook terminus. Here there is an available fall of 28 ft. in the Camlough stream, down which there is a minimum flow of 3,000,000 gallons per day. The turbine is an inward flow vortex wheel with horizontal shaft, from which the dynamos are driven by belts. The turbine runs at 290 revolutions per minute, and has a maximum power of 62 horse-power.

There are two Edison-Hopkinson generating dynamos, shunt wound, giving 72 amperes at a tension of 250 volts and 1,000 revolutions per minute. One dynamo is sufficient for working the whole line. The

resistance of the field magnets of the generator is 72 ohms, and that of the armature 0.12 ohm; their commercial efficiency is about 90 per cent.

The conductor is of channel-steel laid midway between the rails, and carried on wooden insulators nailed to alternate sleepers. For jointing, double fishplates placed externally are used. At the crossings of roads the channel is interrupted, and the current is conveyed by an insulated cable beneath the sleepers. As none of these crossings are wider than the length of the car, the leading collector makes contact on one side of the crossing before the back collector breaks on the other. At one point of the line there is a crossing 150 ft. in length; here a copper wire is slung centrally from cross-bars carried on posts and 15 ft. above the road-level; an overhead collector makes contact with this wire before the back collector leaves the ground conductor. The insulators of the channel steel are blocks of poplar wood, 5 in. long, dried, and boiled in paraffin. The measured insulation of the conductor, under unfavourable circumstances as regards weather and at a tension of 250 volts, is about 900 to 1,000 ohms per mile. This represents a loss through leakage of $\frac{1}{4}$ ampere, or $\frac{1}{10}$ horse-power per mile.

The return circuit is formed by the rails of the permanent way, which are connected one with the other by copper strips.

Each motor car is fitted with an Edison-Hopkinson dynamo as motor, fixed on the leading bogie. The armature shaft carries a double helical toothed steel pinion, 6.05 in. in diameter, gearing into a steel wheel 21.08 in. in diameter, carried on a countershaft running in bearings carried by the bed-plate of the motor. This shaft carries a chain pinion of 8.8 in. in diameter, driving by means of a Reynolds' chain on to a wheel of 21 in. in diameter, keyed on the back axle of the bogie. The wheels of the bogie are 28 in. in diameter, and connected externally by coupling rods. The motors are series wound, so that with a current of 72 amperes the field magnets are nearly saturated. The resistance of the field magnets is 0.113 ohm, and that of the armature 0.112 ohm. The speed is regulated by means of resistances inserted in series with the motor, and which are cut out when the normal speed has been attained. The trains are generally composed of one locomotive car and three or four trucks, but frequently a second passenger car is coupled and the number of trucks is increased. A gross load of 30 tons is thus drawn at a speed of six or seven miles per hour, on a gradient of 1 in 50.

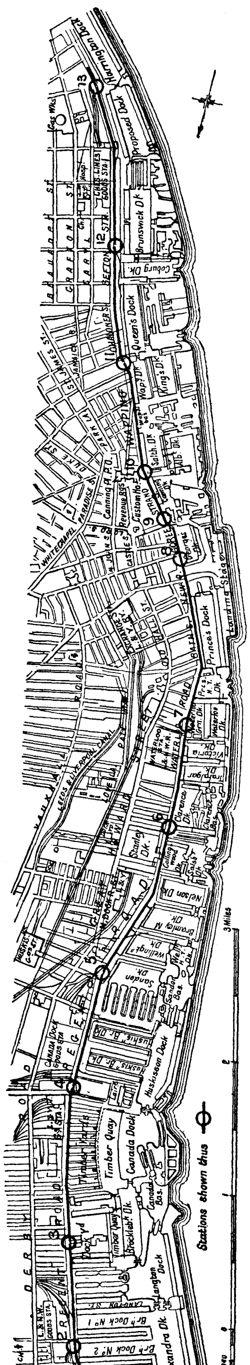


FIG. 402. PLAN OF LIVERPOOL OVERHEAD RAILWAY.

THE LIVERPOOL OVERHEAD RAILWAY.—About seventeen years ago, it became apparent that the low-level lines of railway which traversed the whole length of the dock estate, having connections with the different goods stations along its margin, were becoming so overcrowded by the dock traffic as shortly to render it impossible, consistently with the public convenience, to allow the omnibuses which had been permitted by the Dock Board under special restrictions, to continue to use those lines. For that reason, combined with the overcrowding of the adjoining streets, some other means had to be provided for the expeditious transit of the public. The surface being fully occupied, improved facilities would have to be obtained by the construction of a new line of communication either under or above the surface. An overhead structure was considered the only practicable solution. An Act was obtained by the Dock Board in 1882 for the construction of the railway at an estimated cost of about £585,000.

The Board in 1887 applied to Parliament for power to lease the undertaking to an independent company, and the present Overhead Railway Company was incorporated by an Act in the following year, with power to undertake, by agreement with the Dock Board, the construction and maintenance of the railway. The contract for the structure was let to Mr. J. W. Williams, to whom is due, in no small measure, the successful execution of this important work.

The columns supporting the structure are placed generally vertically under the ends of the main girders, about 22 ft. apart from centre to centre, giving sufficient width above for two lines of standard gauge, with a 6 ft. way between them, admitting of the use of carriages of full width (8 ft. 6 in.) and below for the two lines of dock railway.

The length of the railway, including the short northern extension, but exclusive of an authorised southern extension now under construction, is about $6\frac{1}{3}$ miles (see Fig. 402). There are in all thirteen stations in use, and it is intended to add four more. The gradients are easy, but owing to the position of the Lancashire and Yorkshire Railway at Wellington Dock, the Overhead Railway had to be carried underneath that railway, which entailed a short gradient of one in forty on each side of the coal railway.

Fig. 403. Opening Bridge on Liverpool Overhead Railway.

The sharpest curve is of 7 chains radius. Where the line crosses the entrance of the Stanley Dock, a swing bridge has been provided, both for the dock goods lines and general traffic, and for the overhead railway. At three points, opening bridges had to be provided to permit boilers and other high loads to pass the structure (Fig. 403), and at these points lift or tilt-bridges have been introduced, as being the simplest and most convenient type.

The columns supporting the viaduct consist of two steel channel-bars rivetted to two steel plates, forming a box-column with all the rivet-heads

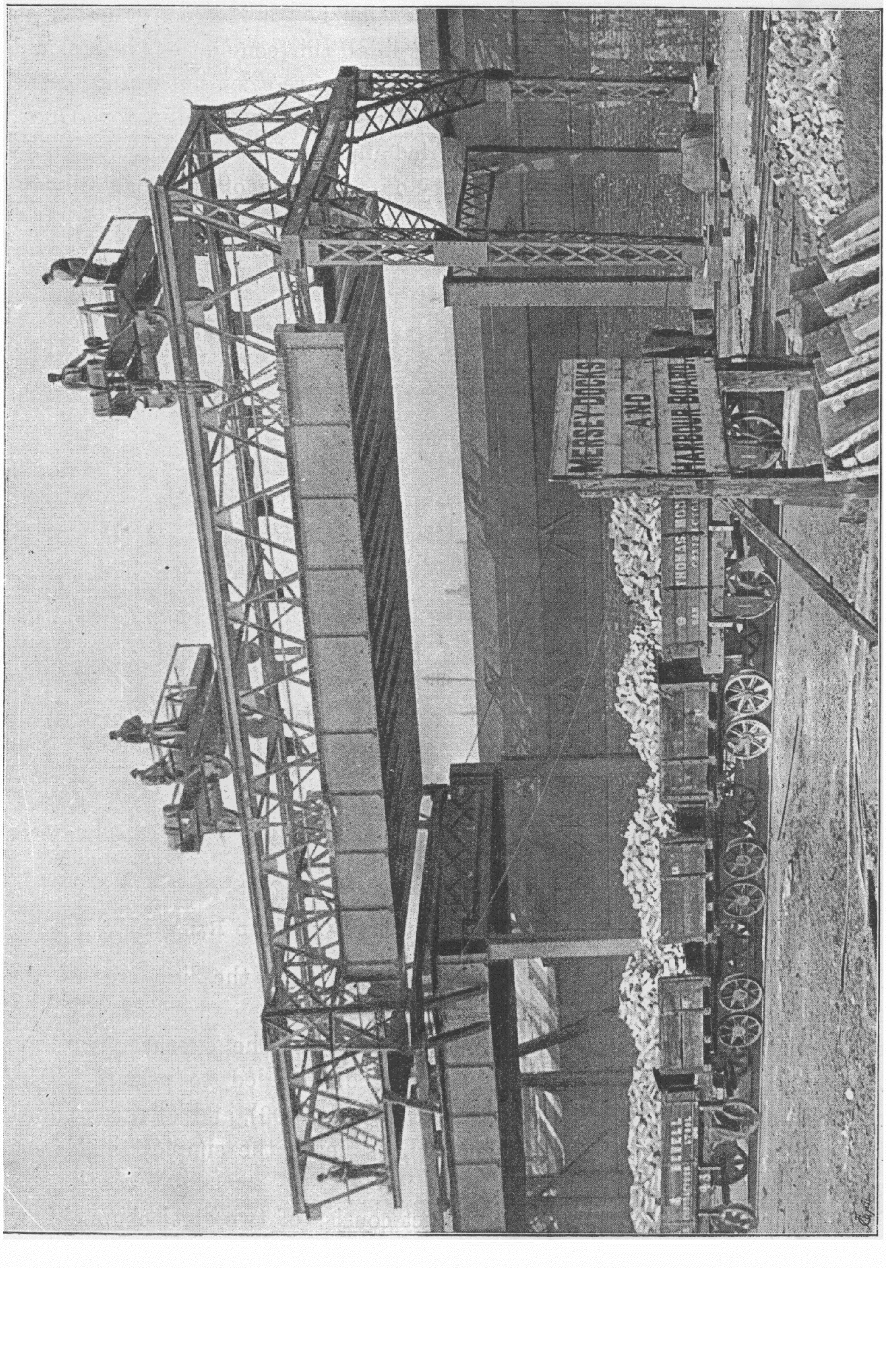


FIG. 404. ERECTING SPAN ON LIVERPOOL OVERHEAD RAILWAY.

outside. These columns are grouted into cast iron-sockets, bedded in and bolted through the blocks of concrete which form the foundations. Cast-iron bumpers, filled with cement concrete, protect the columns against injury from passing wagons.

Between the girders is fixed Hobson arched-plate flooring, consisting of $\frac{5}{16}$-in. plates, bent to a radius of 12 in., with a flat surface 6 in. wide on the top, riveted to intervening T-irons and made watertight by asphalte placed in the V-channels between the arches. On this are laid longitudinal creosoted sleepers keyed to the flooring; no ballast is used. From each V-channel an outlet for water is provided through the web of one of the main girders.

The flooring was made by means of a special plant erected at the northern end of the railway for the purpose, and the girders were delivered by rail at that point.

The structure was so designed that the spans could be put together and riveted up with floor complete at any part of the railway, and be then transported over the completed portion of the structure and placed in position (Fig. 404). The erecting of staging, and interference with the traffic in the streets and upon the dock estate, were almost entirely avoided. The girders were lifted by travelling cranes on to supports above the deck of the structure at the north end, where the flooring was attached to them, thus making each span a complete bridge—a 50-ft. span and its flooring weighing about 22 tons. They were then placed upon a trolley at such a level as to be higher than the main girders of the structure; the trolley travelled on the two outer rails of the permanent way, having a gauge of 16 ft., and at first was hauled by horses on the roadway below, but later by a specially-designed steam locomotive along the already completed portion of the structure.

A special form of erecting apparatus was provided, consisting of two lattice-girders standing upon legs resting on the ground at the front end, and at the hinder end supported on the girders already in position. These lattice-girders were placed at such an altitude as to allow the trolley carrying the succeeding span to be rolled along underneath them. On these lattice-girders were placed two travelling cranes, so arranged as to lay hold of the spans on arrival, run them forward, and deposit them in their permanent positions upon the columns which had been erected in advance. The average time occupied in attaching the traveller to a span, running it forward, and finally dropping the span on its bearings, was one hour. The

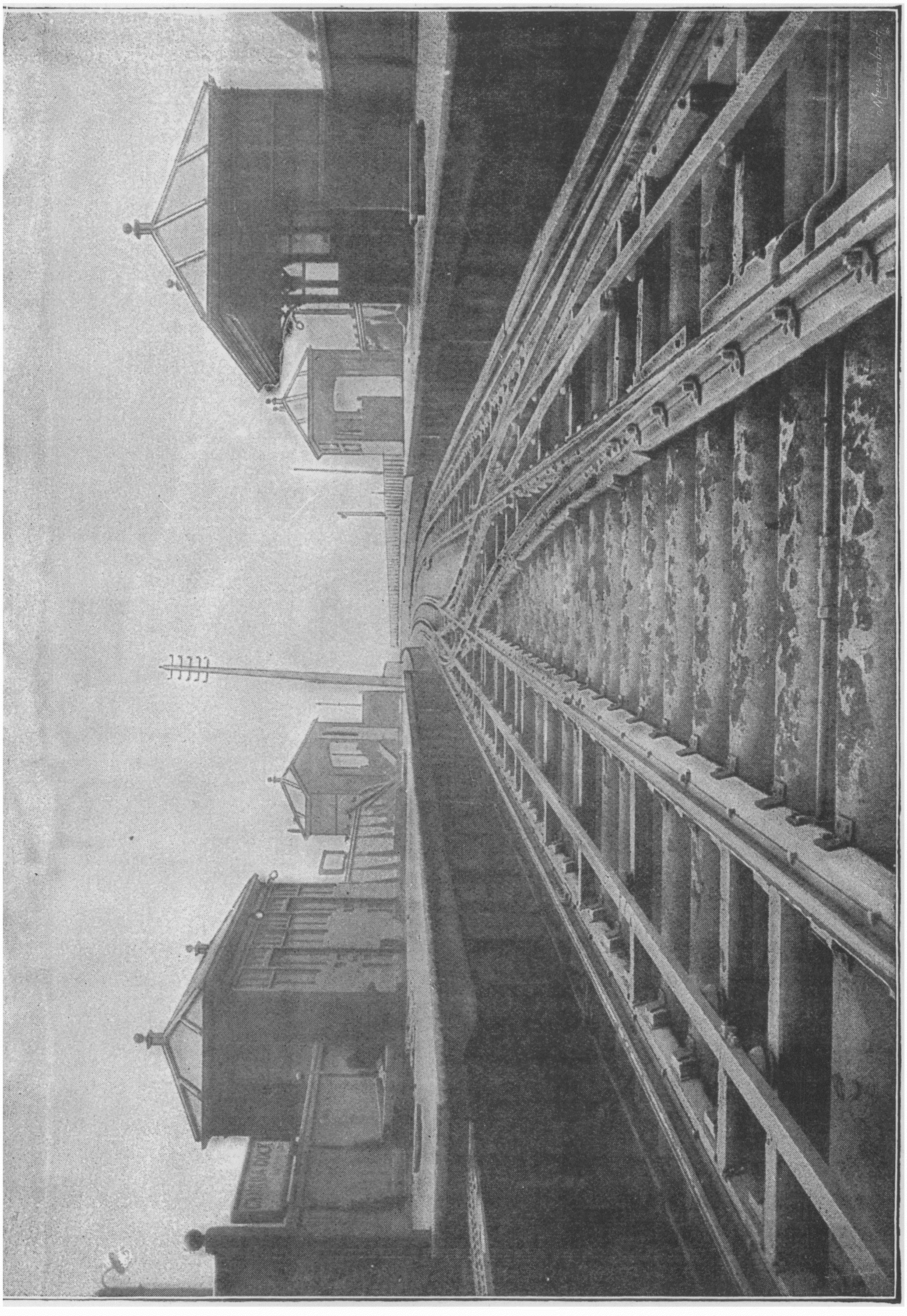


FIG. 405. TRACK CONSTRUCTION OF LIVERPOOL OVERHEAD RAILWAY.

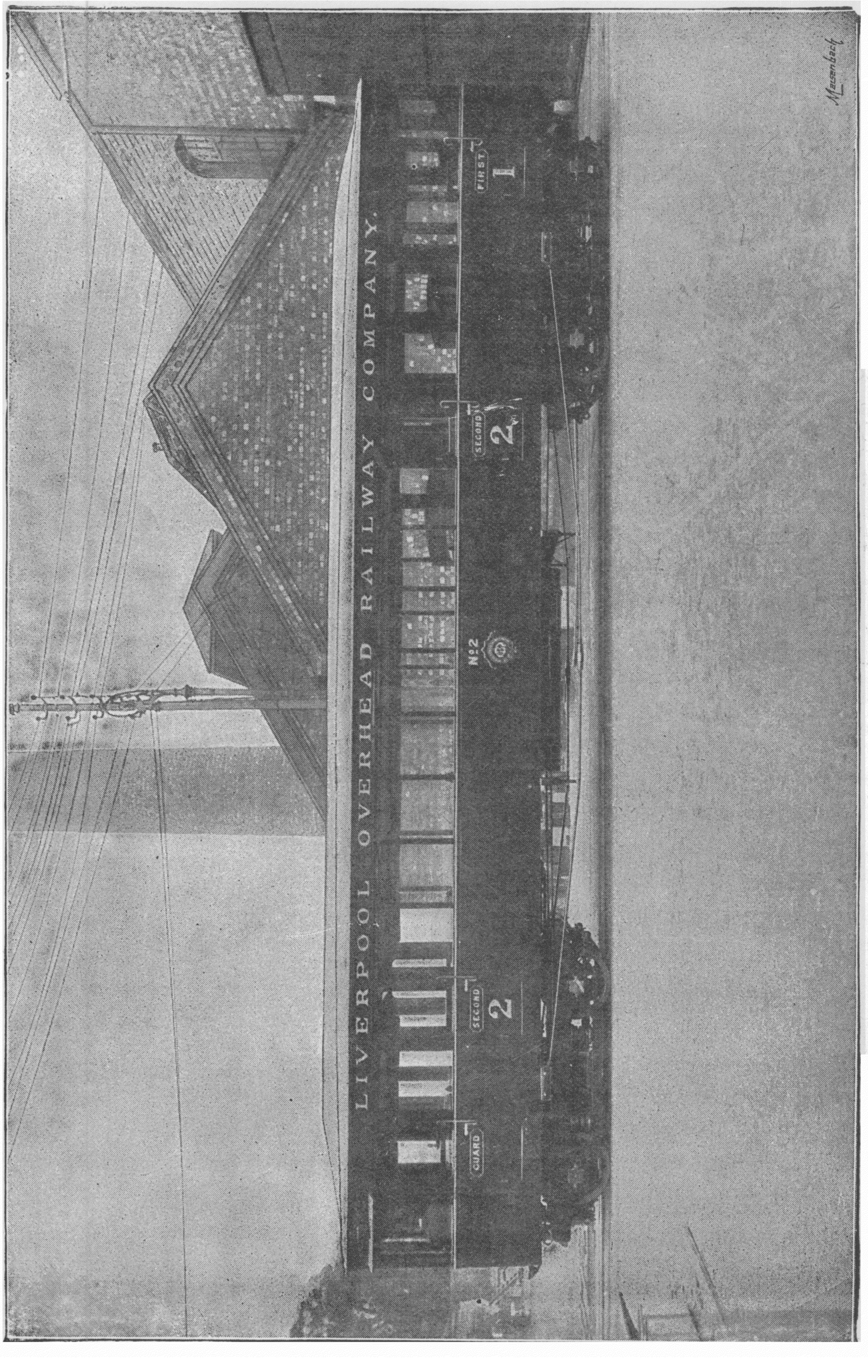


FIG. 406. MOTOR CARRIAGE OF LIVERPOOL OVERHEAD RAILWAY.

apparatus was then again run forward ready for the next span. The total number of spans is nearly 600.

The stations are of a very simple character and design, with the exception of those at "Pier Head" and "Custom House," which are somewhat more extensive. They consist of up and down platforms (island platforms being found to be impracticable), which are 120 ft. in length and 10 ft. in width, each provided with a staircase, turnstiles, ticket office, and a waiting shed. At "Custom House" and at "Pier Head" (St. Nicholas Place), the platforms are roofed, and duplicate staircases are provided, so as to keep the arrival and departure traffic distinct. A carriage shed has been erected at the north end, with five lines of way running through at the rail level, communicating by means of a hoist with the lines and the repairing shop at the ground level, equipped with the necessary tools driven by electric motors.

The permanent way consists of flat-bottomed steel rails, weighing 56 lb. per yard, fixed on longitudinal timbers which are held down to the floor by iron lugs riveted on to it, and oak keys (Fig. 405). On the curves these timbers vary in thickness according to the necessary super-elevation of rail. The rails are fixed by spikes and fang-bolts, special care being taken in fixing them to avoid metallic contact with the main structure. The electrical conductor consists of a steel bar 4 sq. in. in section, of ⊓ form, is placed midway between the rails of each line, and is carried on porcelain insulators supported by cross-timbers.

One train consists at present of two carriages (Fig. 406), each 45 ft. long and 8 ft. 6 in. wide, on two bogies (Fig. 407), 32 ft. apart from centre-pin to centre-pin, with 2 ft. 9 in. wheels, 7-ft. wheel base, and pressed steel frames. The carriages are all exactly alike, and contain accommodation for 16 first-class and 41 second-class passengers in each carriage, with three side doors and a passage from end to end. The first-class passengers are at one end of the carriage, and the driver's box, with switches, etc., is at the other. When the two carriages are coupled together to form a train, the drivers' boxes are at the extreme ends, and the two first-class compartments consequently together in the middle of the train. A small door through the contiguous ends of the carriages enables the guard or attendant to pass from end to end of the train.

The armatures of the motors are directly wound on the axles, and each motor occupies the front half of the bogie-truck. The magnets are of the "horizontal double circuit" type, and are maintained in correct relation to

the armature-axle by two cast-iron flitch-frames, carried by forged extensions of the magnet yokes. The weight of the magnets is taken off the axles by means of adjustable springs suspended from the bogie-frame, and attached to brackets at each end of the motor. The motors are series-wound, and develop 40 horse-power for any length of time without undue heating. The armature resistance is 0.67 ohm, and that of the field magnet coils is 0.37 ohm. The tractive force of each motor at the rim of the wheels (2 ft. 9 in. in diameter) with 100 amperes is 1,450 lb. The weight of each motor with its axle, but without the wheels, is 3 tons, and that of the motor-truck complete is 5 tons 7 cwt.

The trains are fitted with the Westinghouse automatic brake, deriving

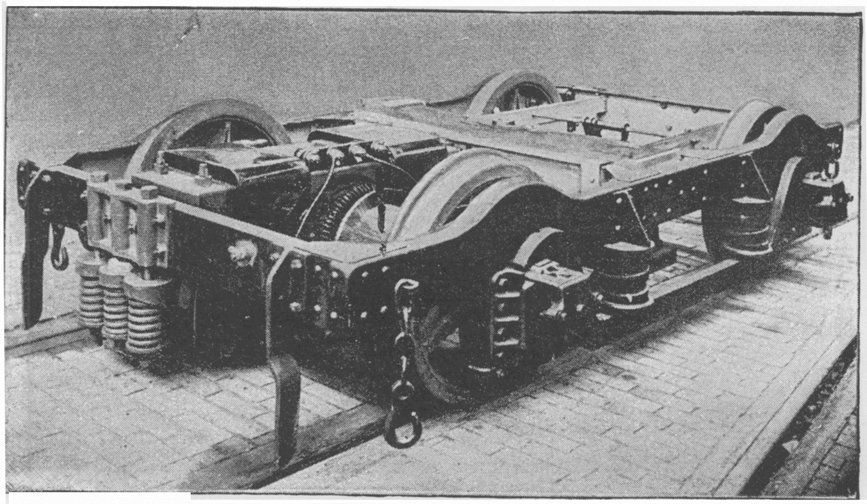


FIG. 407. BOGIE OF MOTOR CARS ON LIVERPOOL OVERHEAD RAILWAY.

its supply of compressed air from a reservoir on the train; the reservoir having a capacity sufficient for two complete journeys, and being re-charged each journey from a receiver placed at the terminus at the north end of the line. The air-compressors are in this case worked by a small electric motor with a gas-engine in reserve. A hand-brake is also provided at each end of the train. The carriages are lighted by 32 candle-power incandescent lamps connected with the working current, and the stations are lighted by similar lamps connected with a battery of accumulators placed under one of the platforms at each station. These batteries are in duplicate, and are charged in series by the main generating dynamos. The Electric Construction Corporation was intrusted with the contract for the electrical equipment and rolling-stock.

The switch-gear is so arranged that when two cars are coupled together to form a train, there is a driving-box at each end. But only one set of handles is provided for manipulating the switches, and these the driver takes with him. Either the driving or trailing motor can be plugged into circuit at will. The switches comprise a magnetic cut-out switch for making and breaking circuit, and a series parallel driving-switch which arranges the two motors first in series and then in parallel. A reversing switch is also interlocked with the driving-switch, which must be turned to the series position before the current can be reversed.

It was important, to secure economical working, that coal should be obtainable by railway direct without the expense of handling and carting;

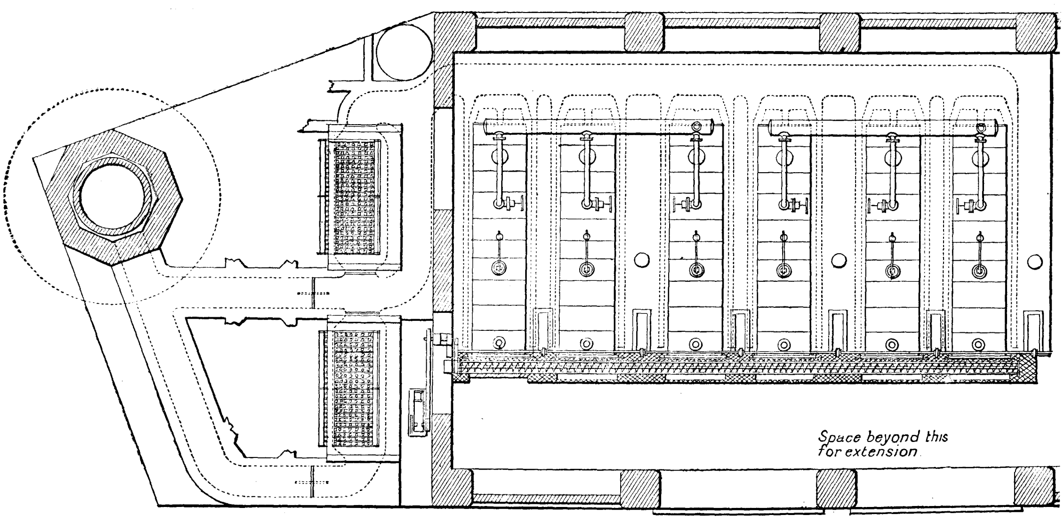


FIG. 408. PLAN OF BOILER HOUSE, LIVERPOOL OVERHEAD RAILWAY.

that a good supply of water should be available for condensing purposes; and that the station should be near the middle of the line. These conditions were fairly satisfied in the site selected under the arches of the coal-railway of the Lancashire and Yorkshire Railway Company at Wellington Dock. The coal is here tipped direct from the railway trucks into large hoppers placed over the boilers, and is distributed by a conveyor to the shoots of the Vicars mechanical stokers with which the furnaces are fitted. Water from the adjacent dock is used for condensing, and the town water for the boilers.

The electrical equipment of the power-plant consists of four dynamos for the generating-plant, each having a normal output of 475 amperes at

500 volts, at 420 revolutions per minute, or say 1,200 engine horse-power in all. Figs. 408 and 409 show the arrangement of the generating plant.

The boilers are of the double-flue Lancashire type with cross tubes; they are of steel, six in number, each 8 ft. in diameter by 30 ft. long, with a working-pressure of 120 lbs. per square inch, and Green economisers in duplicate are fixed in the main flues. The steam and feed-pipe ranges are also in duplicate. The engines are four in number, each consisting of a pair of horizontal compound condensing engines, built by Messrs. Musgrave and Co., of Bolton. The high-pressure cylinders are $15\frac{1}{2}$ in., and the low-pressure 31 in. in diameter, with a stroke of 36 in., fitted with Corliss valves driven by Trip gear, acted on directly by the governor. Each engine will develop 400 indicated horse-power

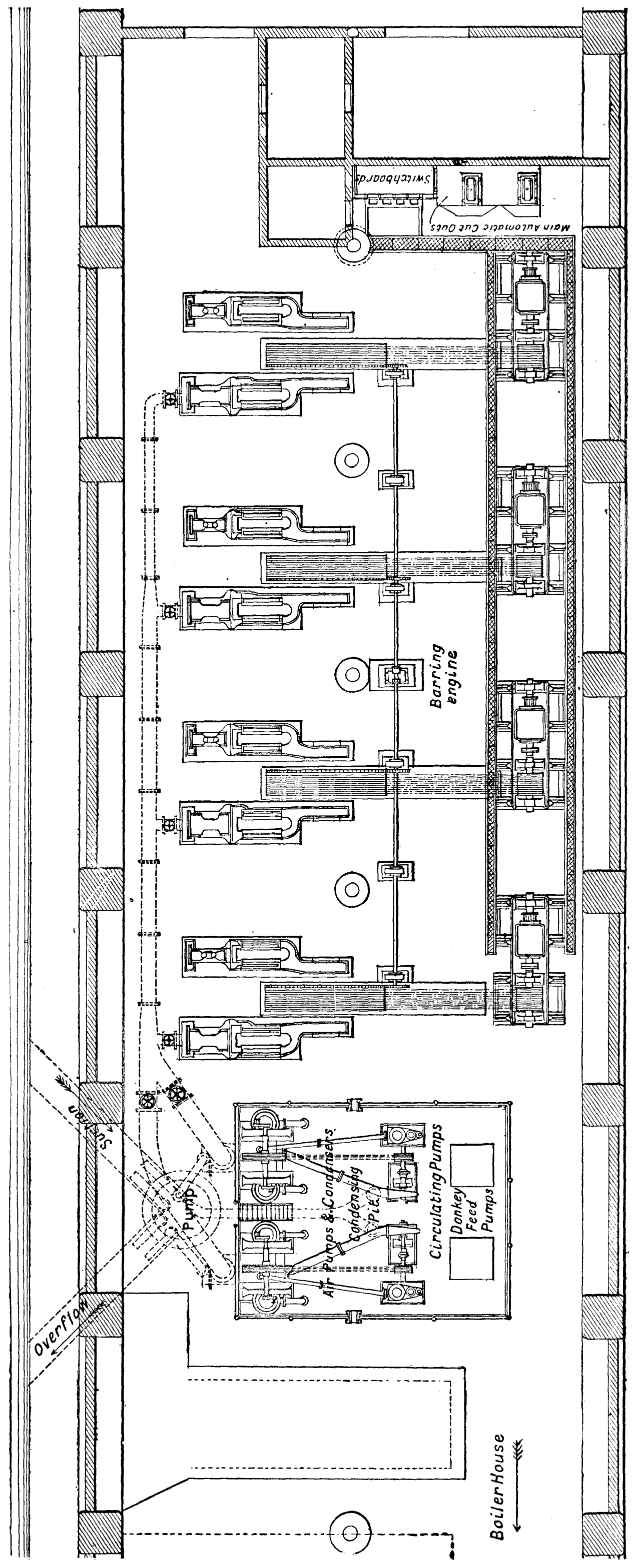


Fig. 409. Plan of Engine Room, Liverpool Overhead Railway.

at 100 revolutions per minute, with 120 lb. boiler-pressure. All the engines exhaust to one condenser of the tubular surface type. The centrifugal circulating pump and air-pumps are driven by a Musgrave "No-dead-centre" vertical compound engine, and the condensing-plant is in duplicate.

Each engine drives an Elwell-Parker dynamo, from which the current is conveyed north and south along each line of the railway by the steel conductor already described. Hinged collectors of cast-iron, sliding upon this conductor (Fig. 410), the top surface of which is about $\frac{3}{4}$ in. higher than rail level, allow the current when required to pass through the motors,

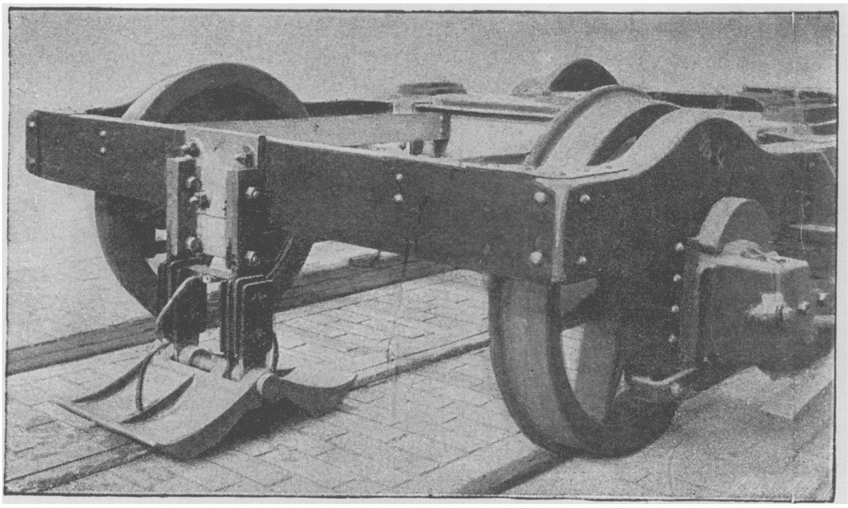


FIG. 410. SLIDING CONTACT, LIVERPOOL OVERHEAD RAILWAY.

and to return by the wheels and the rails to the dynamos. At the crossings the conductor is bent to form wings parallel to the rail to be crossed, in the same way as is usually done at rail crossings.

The dynamos are of the double limb type, with a magnetic circuit above and below the armature, the poles being cut through horizontally along the centre line to allow the upper part to be lifted readily. They are shunt-wound, of "drum" type, with stranded conductors. The resistance of the armature is 0.01 ohm, and that of the shunt is 75 ohms, the electrical efficiency of the machines being 97.7 per cent. The armature and shaft weigh three tons, and the complete machines $21\frac{1}{2}$ tons each. Each dynamo is driven by nineteen $1\frac{1}{4}$-in. cotton ropes, from a horizontal compound engine, indicating 400 horse-power at full load.

The armature-shaft carries a half-coupling by which it is connected to the pulley-shaft, which runs between two bearings; the armatures can thus be easily removed without disturbing the pulley and ropes.

The current from each dynamo is carried to common omnibus bars through an ammeter and automatic magnetic cut-out, so that all can work in parallel. These cut-outs are also used as switches, and are thus always kept in working order. They are adjusted to break the circuit automatically when the current exceeds 1,000 amperes.

From the omnibus bars the current passes through a main magnetic cut-out (adjusted to break circuit with a current of 3,000 to 4,000 amperes) to the centre conductor, from which the moving trains collect their current.

The working expenses for motive power are about 4d. per train mile. With a train mileage equal to that of the Ninth Avenue line, the cost would probably not exceed 3d. per train mile. The actual average consumption of coal is about 16 lb. per train mile for trains of 38 tons weight, with seating capacity for 114 passengers, running at an average speed, including stops at stations, of about twelve miles per hour; the averages on the New York Elevated Railways are, approximately, 54 lb. of coal per train mile for trains of about 92 tons weight (including locomotives weighing 23 tons) running at an average speed of about twelve miles per hour, including stops at stations. On the Liverpool Railway, during the last half-year, over 98 per cent. of trains were punctual to time. The coal used at Liverpool is bituminous small coal (slack), whilst in New York it is anthracite of good quality. The New York fuel consumption includes the heating of the trains in cold weather; but, on the other hand, that of the Liverpool line includes the lighting of trains and stations and the working of the automatic signals. The working of the brakes is included in both cases.

It will thus be seen that electric traction is actually less expensive after full allowance is made for the difference in the weights of trains and other circumstances, in the two cases considered; and when the mileage of the electric line increases, the difference will be still more marked in its favour. Table XCVII., which is taken from a paper read by S. B. Cottrell before the British Association, gives some very interesting comparisons of receipts and expenditure on this line.

The Liverpool empty train weighs 31 tons $2\frac{1}{2}$ cwt., of which the electrical equipment for locomotion weighs 6 tons 7 cwt. With all seats occupied by passengers, the total weight is about 38 tons 6 cwt. The

weight of locomotive equipment is thus about 125 lb. per passenger, or about 20 per cent. of the total weight of the train with all seats occupied, each passenger being taken at 140 lb. weight. A comparison of these figures with those of trains on other railways using electric and steam locomotives is given in Table XCVIII.

TABLE XCVII.—Giving Comparative Statement of Receipts and Expenditure on Liverpool Overhead Railway.

	Liverpool Overhead Railway.			
Half-year ending	Dec., 1894.	June, 1895.	Dec., 1895.	June, 1896.
	d.	d.	d.	d.
Value per passenger	1.67	1.92	1.97	1.96.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Expenditure to revenue	66.84	66.43	59.97	63.05
Locomotive expenditure to gross expenditure	24.78	24.26	26.05	22.51
Locomotive expenditure to gross revenue	16.56	16.12	15.62	14.19
Traffic expenditure to gross expenditure	38.88	37.54	35.33	36.05
Traffic expenditure to gross revenue	25.99	24.94	21.19	22.73
	d.	d.	d.	d.
Expenditure per train mile	13.10	14.38	14.11	15.10
Revenue per train mile	19.59	21.65	23.53	23.95
Locomotive expenditure per train mile	3.25	3.49	3.68	3.40
Number of passengers conveyed	3,641,379	3,460,060	3,788,375	3,739,575
Train mileage	314.472	311.346	321.417	313.010
Number of stations	16	16	16	16
Percentage of train punctuality	95	96.8	98.4	98.3

TABLE XCVIII.—Table giving Comparative Weights of Trains on Liverpool Overhead, and other Lines.

Items	Electric Motor Cars.	Electric Locomotives.	Steam Locomotives.	
	Liverpool Overhead Railway.	City and South London Railway.	Manhattan Railway, New York.	Great Northern Railway, Suburban Train.
	tons. cwt. qrs.	tons. cwt. qrs.	tons. cwt. qrs.	tons. cwt. qrs.
Weight of motors or locomotive	6 7 0	10 7 0	23 4 0	53 10 0
Number of passenger seats in train	114	96	240	414
Weight of motors or locomotive per passenger, in pounds	125	241	217	290
Weight of full train (all seats occupied)	38 5 2	37 7 0	104 1 0	188 11 0
Weight of motors or locomotive relatively to weight of full train, *ex* motors or locomotives, per cent.	20	38	29	40
Average weight of empty carriages (*ex* motors) per passenger seat, in pounds	487	490	615	590
Weight of full train per passenger, in pounds	752	871	972	1,020

The signals are of the ordinary semaphore and lamp type, but they are operated entirely by electricity, applied by the motion of the trains without the intervention of signalmen. At each station, and for each line, are a "home" and a "starting" signal, no "distant" signal being necessary—or rather the "starting" signal being the "distant" for the station or "home" in advance. As a train passes each signal it sets it to "danger," by operating a lever which breaks an electric current passing through a contact-box placed at the side of the line.

In order to reduce to a minimum the current required for this work, advantage is taken of the fact that a comparatively small current will suffice to hold an armature after it has been brought into contact with a magnet, by automatically switching in a resistance about the moment that contact occurs; the effect is to reduce the current from that necessary to give the pull to that requisite to hold the signal in the "line clear" position. The lowering-current is supplied by the through circuit, but the holding-current is supplied through a short local circuit, thus freeing the making contacts in advance for another operation. Each train has always at least one signal at "danger" behind it. All the making and breaking contacts are in duplicate, and all the signal lamps have two incandescent lamps in each, in parallel, so that if any one fails the other still gives light. The electric lamps are lit, and the electro-magnets are operated, by a current of 50 volts from a battery of accumulators placed at each station under one of the platforms. The batteries are in duplicate, and while one is discharging the other can be charged. They are charged in series from the main circuit of 500 volts.

In addition to the automatic signals, electric bells are at present used between station and station. These are worked by the porter on each platform, and telephones are in use at all the stations, and are connected with the general manager's office.

The railway was inspected on behalf of the Board of Trade by Major-General Hutchinson, R.E., C.B., Major Cardew, R.E., and Major York, R.E., and having been duly passed, was formally opened by the Marquis of Salisbury, on the 4th February, and opened for traffic on the 6th March, 1893.

The total quantity of iron and steel in the structure is about 22,000 tons. The total capital cost, including equipment and all other charges, has been about £550,000, or about £90,000 per mile of railway. The engineers were Sir Douglas Fox, Member of Council Inst.C.E., and Mr. J. H. Greathead, M.Inst.C.E., who were represented on the spot during the construction of the line by Mr. Francis Fox, M.Inst.C.E., and Mr. S. B. Cottrell, M.Inst.C.E., and who is now the manager of the line.

CHAPTER XXVI.

COMBINED LIGHT AND POWER PLANTS.

THE longer an electric plant can be kept running, and the smaller its idle reserve comparatively, the cheaper the cost of production, and consequently the lower the selling price of power will be. Machinery which lies idle depreciates, and as it does not contribute to earnings, this depreciation must be deducted from the earnings of the active plant.

The day load, as electric light engineers call it, is never very heavy in lighting plants. Large factories prefer to generate their own electric power for lighting and driving motors, and the number of motors running small shops is very limited. If the cost of electric energy to the consumer could be reduced, this number could be very much increased. The electric station engineer has for years been seeking a day load, and the supply of electrical power for traction purposes will give this day load. The large traction station with machinery running for 20 out of the 24 hours can produce power very cheaply, notwithstanding very rapid and constant variation of the load. The supply of light, as well as power, from the same station would be of value, as it would somewhat reduce the comparative variations. Combined lighting and traction plants work well.

The largest amount of power for lighting is required at night or in the very early morning and in winter, while the reverse is the case for traction. The heaviest work of many tramways comes just after places of entertainment are closed or before they open, and in the morning and afternoon hours, when their patrons are travelling between their houses and places of business. For the greater part of the year this travel is before darkness sets in. The superposing of the energy curves of lighting and traction will not do away with the peak which is to be found in every lighting curve, but it will very greatly diminish its relative value, which after all is the important consideration.

It need not be pointed out in detail how great a saving is effected by not requiring a separate staff for each service. This must result from the use of a single station. Relatively a far smaller reserve need be provided

for a combined plant, provided that it has been specially laid out so as to be adapted for both purposes. Where this is not the case, a special reserve will still be required for each service.

One point must be kept in mind, viz., that from the time the current leaves the dynamos, the lighting and power sections must be kept entirely separate, and that separate cables, switchboards, instruments and feeders are essential to the success of such a system. There are three distinct ways in which a combination of traction and lighting plants can be effected:

1. The plant is specially designed for combined working in such a way that the same reserve sets can be used for either purpose. The plant may be an alternating current one, in which case special reserve transforming sets must be supplied for the tramway plant, although the main reserve sets may be the same.

2. Already existing alternating or continuous current lighting plants can be utilised. Motor generators, with or without stationary batteries, must be adopted.

3. The railway power plant is entirely separate from the lighting plant, only the prime energy, either steam or water, being utilised for driving both plants under one roof.

The largest, most complete, and well-thought-out combined plant to be found at present is probably that now running at Hamburg. Through the courtesy of Messrs. Schuckert and Co., of Nuremberg, who designed and equipped this station, we are enabled to give a well-illustrated description of this interesting installation.

A double interest attaches to this plant owing to the fact that the tramways belong to an entirely independent company, which buys its power at so much per unit, and that the rate of charge for power is extremely low. The tramways system of Hamburg is the largest and best developed in Europe. There are at present in Hamburg two power stations from which electrical energy is transmitted, both for power and lighting purposes. The older of these stations will shortly be utilised for lighting purpose only, and the new and larger station will supply all the power required for the tramways as well as doing lighting work. It is this latter station which will be described in detail.

The first electric supply works were erected in Hamburg in the year 1888, and at that time were considered very large, as they had been built to supply 12,000 incandescent lamps and 64 arc lights. They were, however, soon found to be far too small. The town of Hamburg called for tenders

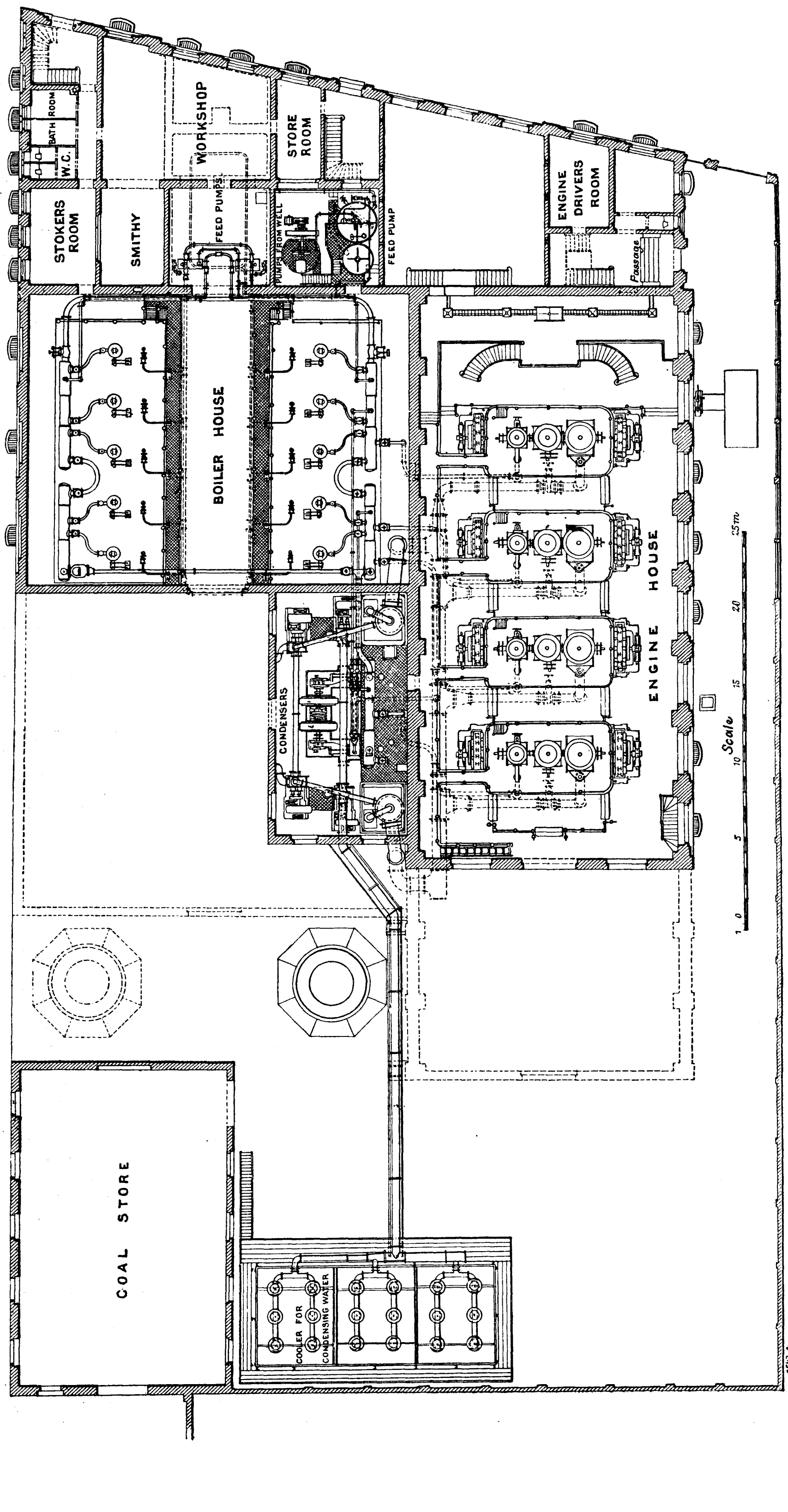


FIG. 411. PLAN OF HAMBURG POWER HOUSE.

for the equipment of a new and larger station, and on May 10th, 1893, a contract was signed by Messrs. Schuckert and Co. for the entire equipment and construction of a power station which should supply power for lighting, motors, and traction purposes, and this new station was put into operation about the end of last year.

The exterior of the building is of brick, and exceedingly handsome. The front is used for offices, besides which the engineers in charge have living rooms provided for their accommodation. Fig. 411 gives a plan of the whole installation. It will be seen that at the present moment there are only four sets of engines and 10 sets of boilers, but that plenty of space is available for enlarging both engine and boiler-house. In fact, at the present moment another engine and four more boilers are being put in. The boiler room is 25 metres wide and 19 metres long (82 ft. by 62.4 ft.).

The engine-room is 17 metres wide, 36.8 metres long, and the clear height is 12 metres (55 ft. wide, by 120 ft. long, and 39 ft. high). In the engine-room there now are four sets of triple-expansion condensing vertical marine engines, connected on each side directly to a 12-pole shunt-wound dynamo. The engines are fitted with Corliss valve gear, and at a pressure of 10 atmospheres (147 lb. per square inch) and 100 revolutions these engines will develop 1,000 to 1,200 brake horse-power each.

The total height of the engine over all is 7.5 metres, or about $24\frac{1}{2}$ ft. The floor space occupied is 8 metres by $4\frac{1}{2}$ metres, or about $26\frac{1}{4}$ ft. by about $14\frac{3}{4}$ ft. The high, intermediate, and low-pressure cylinders are located side by side, and act on to cranks which are at an angle of 120 deg. Each engine is fitted with two flywheels, 4 metres in diameter (about 13 ft.), and each one of which weighs $7\frac{1}{2}$ tons. The governor acts on both the high-pressure and intermediate cylinders. The lubrication of the engines is effected by means of an oil tank, which is placed on the top of each engine, and whence the oil, after having been used in the various bearings, descends, and is collected in a tank which is placed under the bedplate of the engine. From here the oil is pumped back through a filter to the top of the engine, where it is utilised again. Fig. 412 gives a longitudinal section of the engine-room, and Fig. 413 is a transverse section. All the cylinders of the engines are steam-jacketed. The high-pressure and intermediate cylinders are jacketed with high-pressure steam direct from the boilers. The low-pressure cylinder is jacketed with steam coming from the intermediate receiver. All the jackets are furnished with water separators. The diameter of the

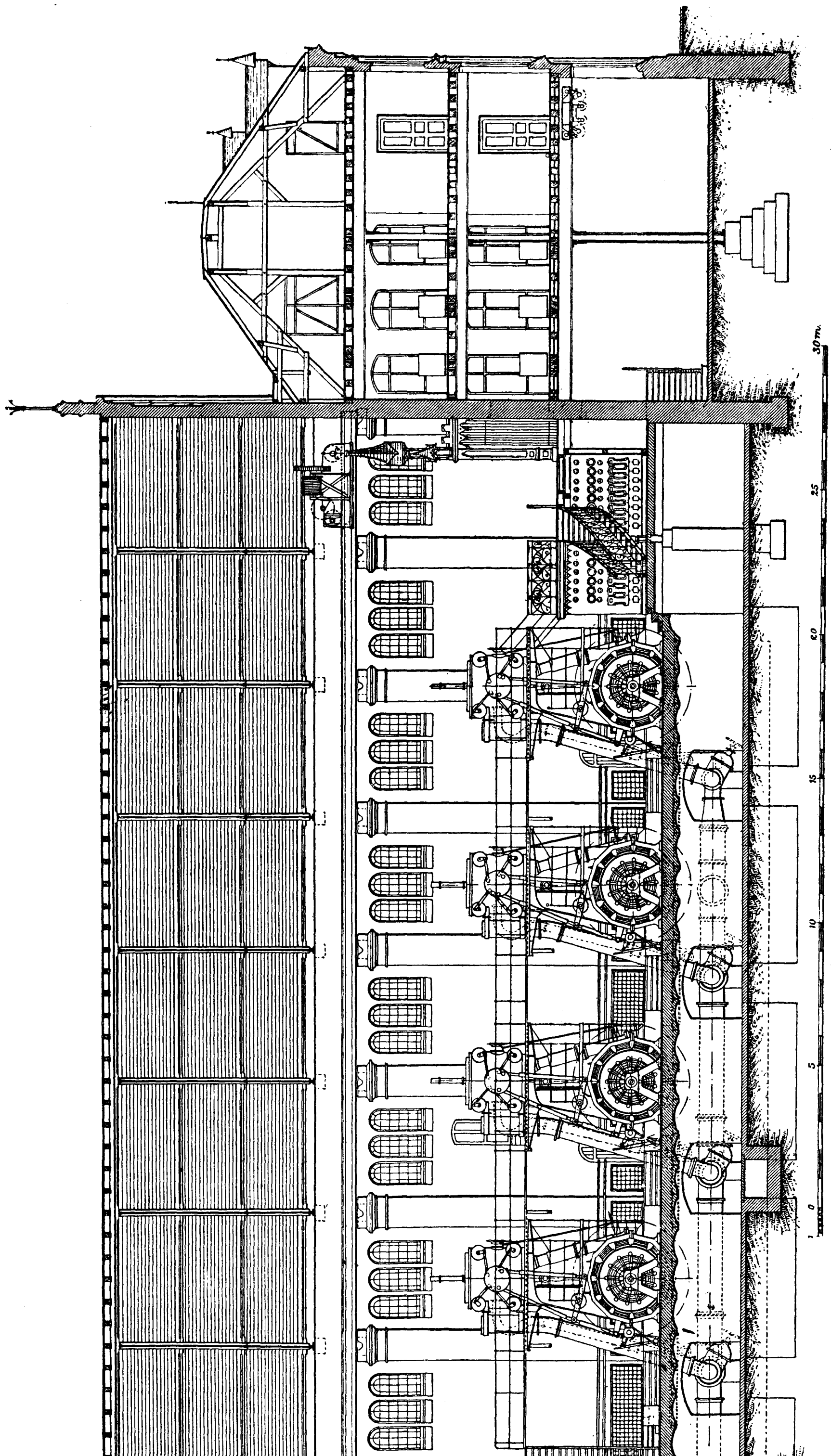


FIG. 412. LONGITUDINAL SECTION OF HAMBURG POWER HOUSE.

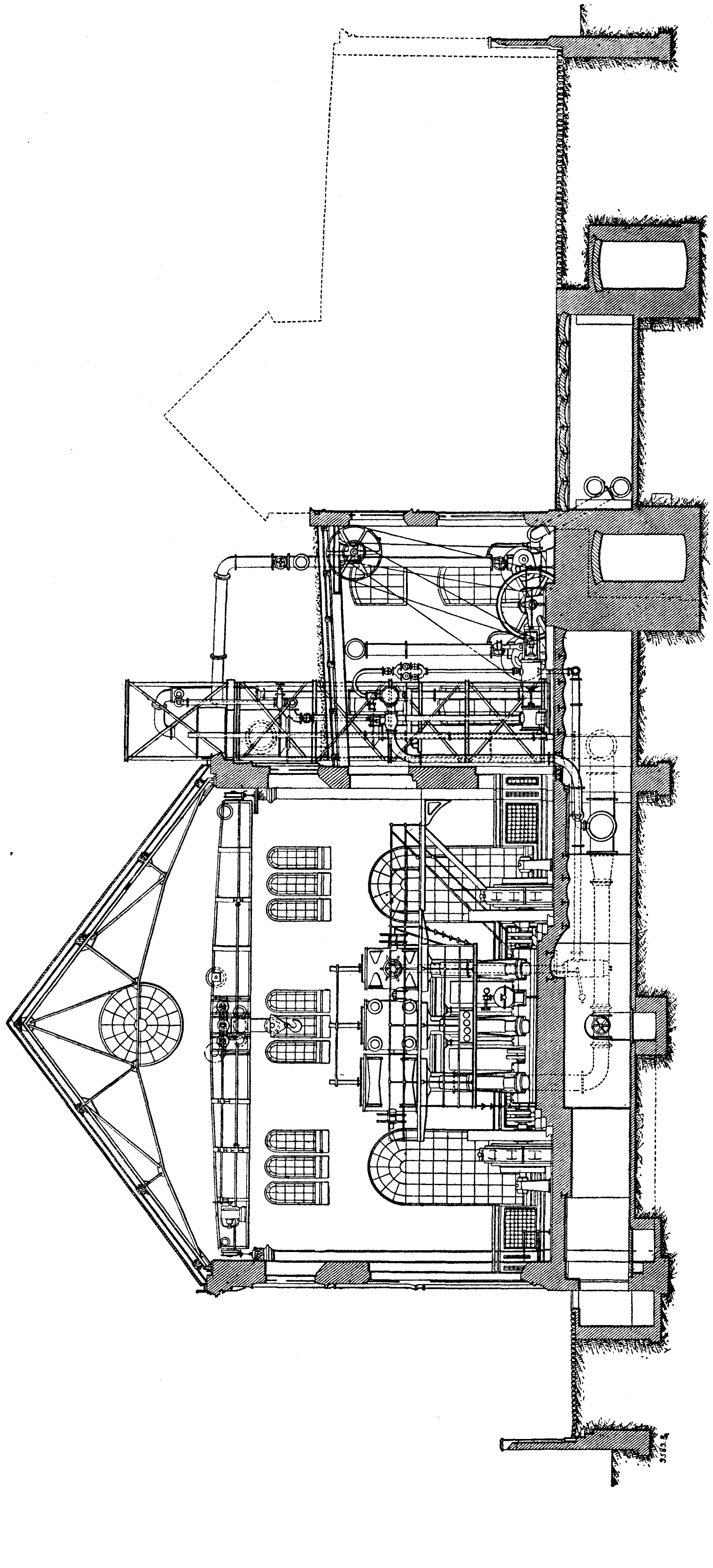


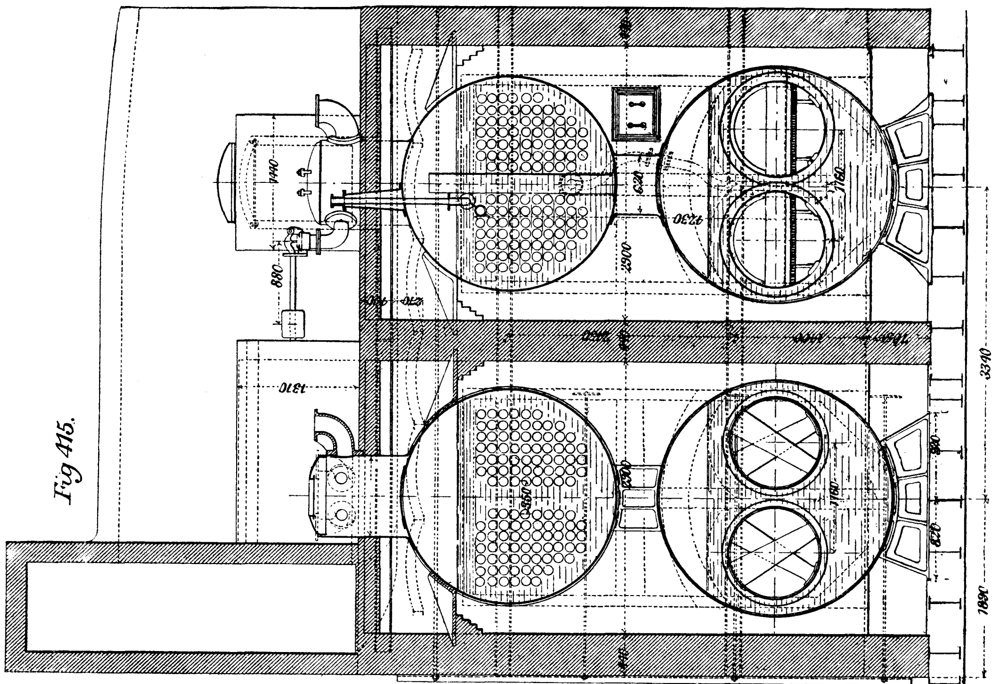
Fig. 413. Cross Section of Hamburg Power House.

high-pressure cylinder is 575 millimetres (22.64 in.); that of the intermediate one is 925 millimetres (36.41 in.); of the low-pressure cylinder 1,350 millimetres (53.15 in.) The stroke is 39.37 in. The steam utilised in the high-pressure cylinder passes through the steam jacket surrounding the same before it enters it. Each engine is directly coupled to two 350 kilowatt generators. All are 12-pole machines shunt-wound, some for a pressure of 250 volts, the others for a pressure of 540 to 600 volts. The latter are mostly used only for railway work. The former can be put in series in pairs, and thus used for railway work, whereas if run in parallel they supply current for lighting purposes, and in that case they work in parallel on a large battery of accumulators, from which a three-wire system is taken for lighting purposes. From the engines the steam goes through a condenser. The condensing plant is driven by two 140 horse-power horizontal engines, the cylinder diameter of which is 514 millimetres (20.24 in.), and the stroke 500 millimetres (19.69 in.) The number of revolutions per minute is 100. The hot water from the condenser is pumped by means of a centrifugal pump, which has a capacity of 8.65 cubic metres (306 cubic feet) per minute, on to the top of a wooden erection known in Germany under the name of "Gradierwerk." This resembles a gigantic sieve. The hot water passes through a series of inclined wooden planes, and the water is constantly changing its direction. This erection is shown in the left-hand corner of the plan, Fig. 411.

The type of boiler used, as will be seen from Figs. 414, 415, and 416, is peculiar, and the advantage claimed for it is the very large amount of heating surface which it presents. It will be seen that, to all intents and purposes, it consists practically of the superposal of a marine and Galloway boiler. The top or marine boiler has 125 fire-tubes, each one 95 millimetres (3.74 in.) in diameter. The bottom boiler has a diameter of 2.4 metres (7 ft. 10.5 in.) and is 5.9 metres (19 ft. 3 in.) in length. Each boiler has a heating surface of 250 square metres (2,691 square feet). The feed water before entering the boilers is heated to 80 deg. Cent. For this purpose it is conducted into iron tanks, situated close to the boilers, and in which the steam from the feed pumps is condensed.

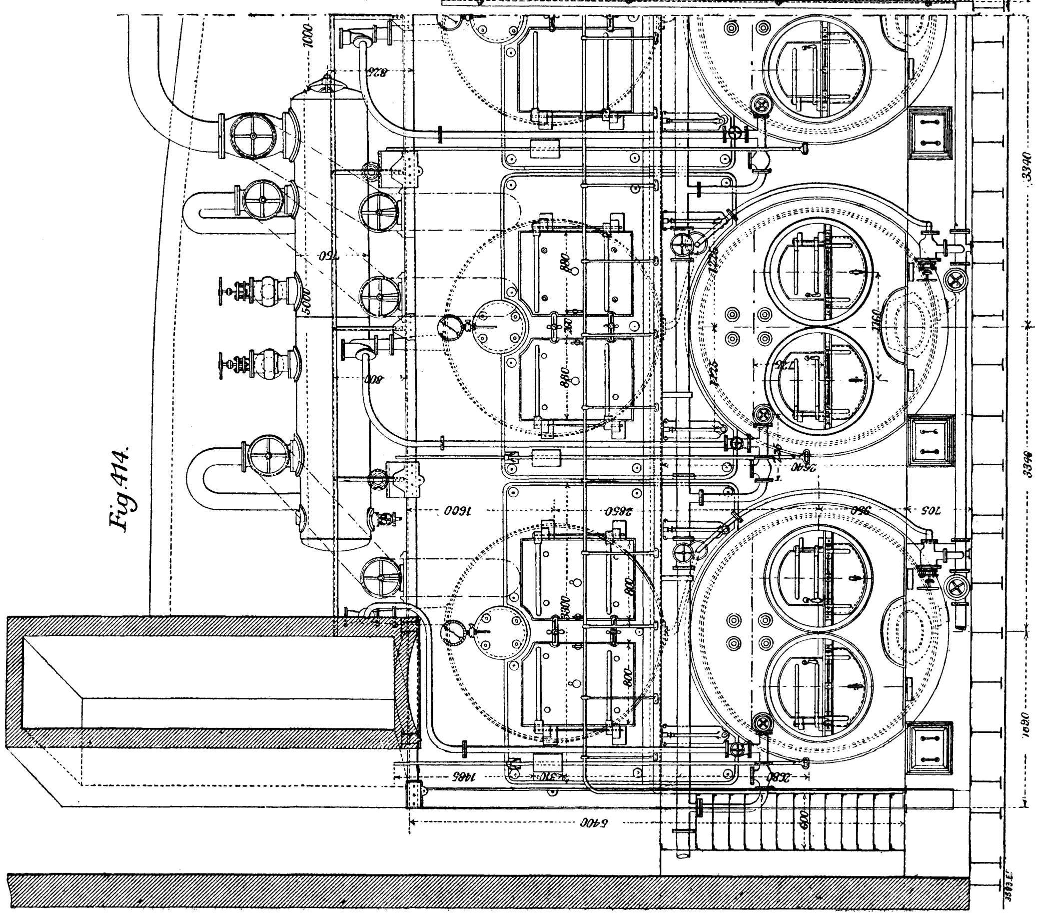
There are two smoke stacks provided for, of which one only has been built so far, 50 metres (164 ft.) high. The coal burnt is Welsh, and a special coal store is located near the water cooling plant. This is connected directly to the railway tracks which run outside the station. An electric traverser runs out and takes the truck with coals into the coal

Fig. 415.



Cross Section through Boilers, Hamburg.

Fig. 414.



Front Elevation of Boilers, Hamburg.

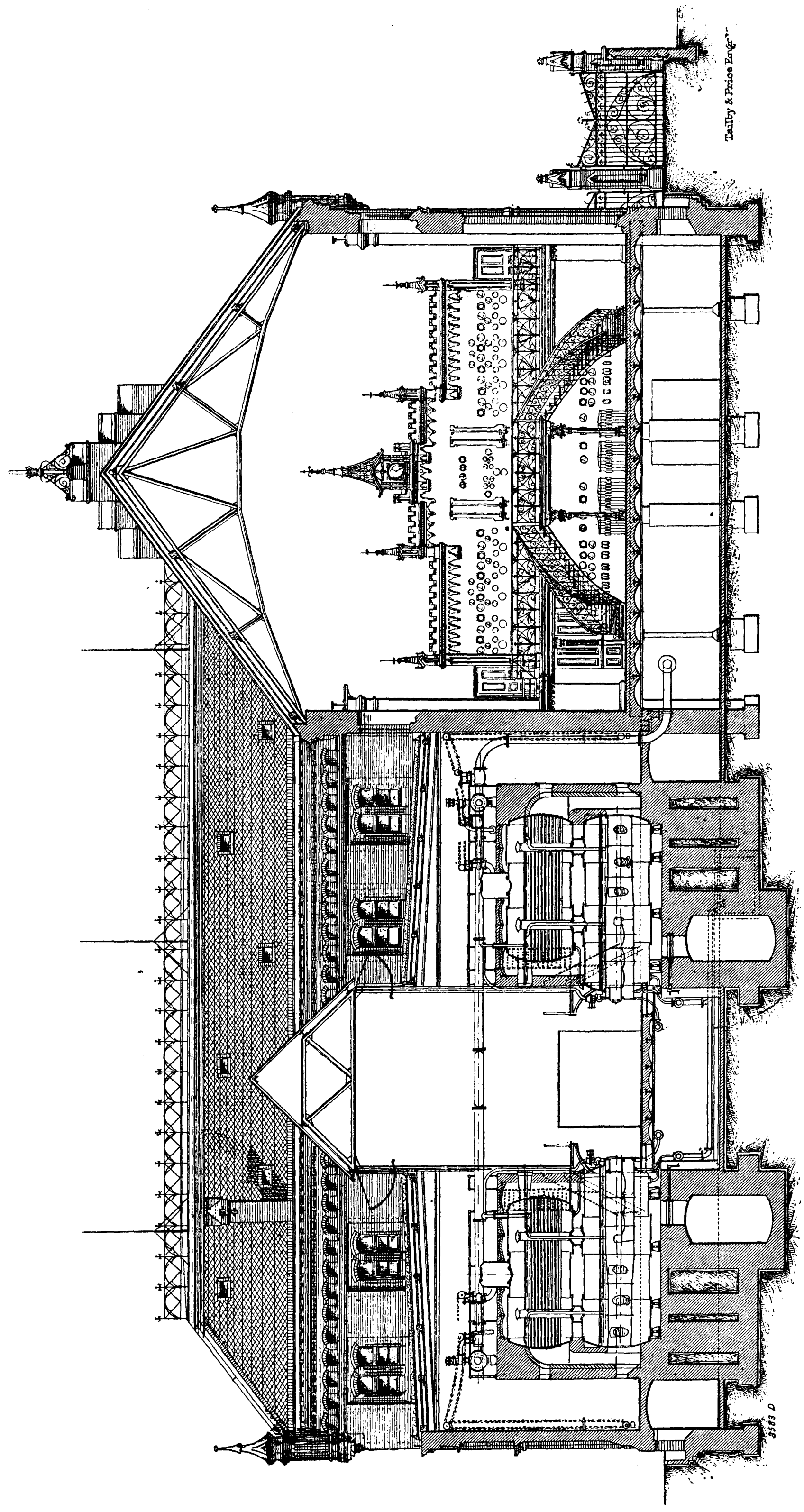


Fig. 416. Cross Section of Boiler House, Hamburg.

shed, and on its way goes over a weighbridge, where the weight of the coals is registered before unloading.

Water being extremely expensive, the company sunk a well to a depth of 187 metres (613 ft.), and from this all the water for the boilers and for condensing purposes is raised by means of a special pump.

Fig. 417 shows in diagrammatic form the connections of the main switchboard in Hamburg, and Fig. 418 the connections of one of the sub-stations which are erected in various parts of the town and from

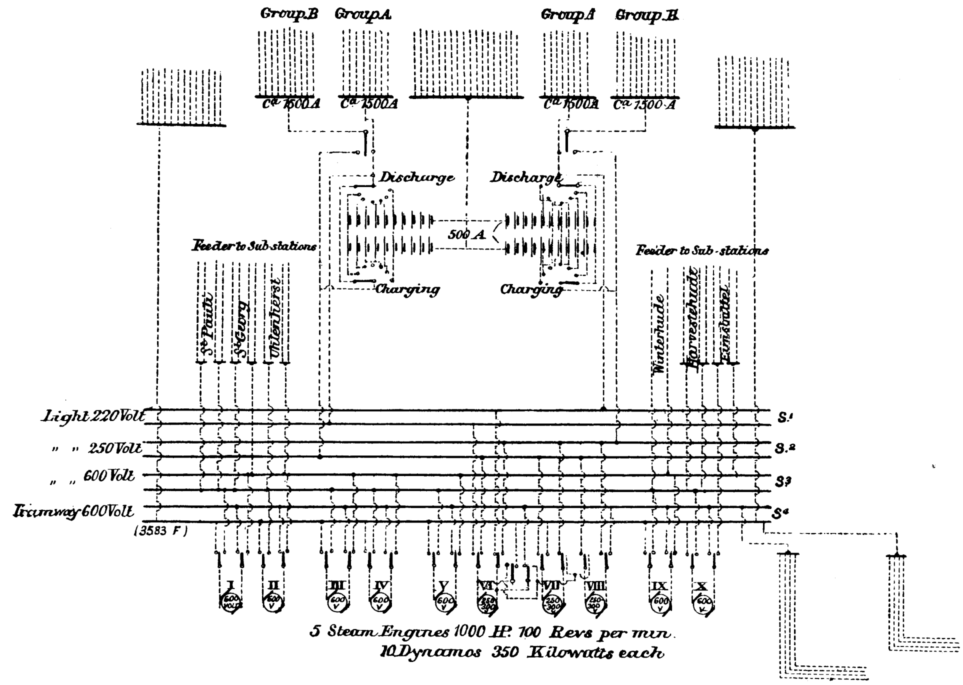


Fig. 417. Diagram of Main Switchboard Connections, Hamburg.

whence current is distributed, both for lighting and traction purposes in the neighbourhood of each station. The batteries of accumulators at the central power station can furnish a current of 1,000 amperes at 250 volts. There are at present installed two such batteries of 140 cells each, and there is room for a third one. The capacity of each of these batteries is 1,570 ampere-hours at 520 amperes discharge, and 405 amperes charging rate. The current is furnished to various sets of bus-bars at pressures of 220, 250, and 600 volts for lighting purposes, as well as to another set of bus-bars from which the current is taken exclusively for tramway work, at from 540 to 600 volts. The bus-bars S 1, Fig. 417, serve to supply the

MMM

current for the feeders for lighting purposes in the neighbourhood. S 2 charge the batteries and also furnish the supply for feeders. S 3 furnishes a current of 600 volts at which pressure current is supplied to sub-stations. S 4 furnishes the current for tramway purposes. At the present moment, of the dynamos in the station, six are wound for 546 volts, and two are wound for 250 to 300 volts.

The lighting is on the three-wire system, but the third wire is only connected to the centre of the two batteries. The regulation of the tension of the feeders is effected on the outside cables. The accumulators possess, therefore, two charging and two discharging switches. The armatures of the generators are Gramme wound in notched cores, and the

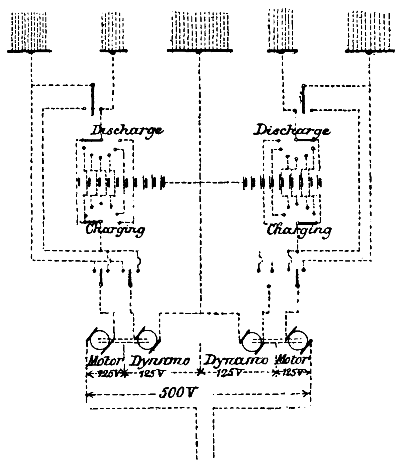


FIG. 418. DIAGRAM OF SUB-STATION SWITCHBOARD CONNECTIONS, HAMBURG.

pole pieces, after the magnet coils have been slipped in place, have pole shoes screwed on. The faces of these are cut on a slant in the direction of the shaft, the object of this being to reduce sparking at the brushes. Carbon brushes are used throughout. An extremely ingenious system is utilised at the sub-stations for subdividing the power, which arrives at a pressure of 500 to 600 volts into four currents, each one at a pressure of 110 to 125 volts. At the present moment six sub-stations have been provided for, the farthest one being three miles from the central station. To reduce the pressure an arrangement shown in diagrammatic form in Fig. 418 has been devised, which consists of having two batteries of accumulators and two motors wound for 125 volts, and each of the latter is direct connected to a dynamo, which furnishes current at 125 volts.

Each motor reduces the pressure to 125 volts, which pressure is transformed in the dynamo to a current furnished at a pressure of 125 volts. By this means it will be seen that four currents are generated at 125 volts each. A battery of accumulators sufficient to give a pressure of 250 volts is supplied in each transformer station. The great advantage of the system is that only half the current has to be transformed down, which, of course, reduces the losses due to transformation by half. Another advantage of this system is that by regulating the field of the generator a higher or lower potential can be obtained.

The tramway companies of Hamburg were allowed by the corporation to erect the overhead trolley wire, the only conditions set being that they would buy power from the existing electric light works.

TABLE XCIX.—Giving Data of Hamburg Electric Tramways.

Increase in receipts over previous year when the lines were worked by horses	34 per cent.
Rolling stock (motor cars)	360
Closed trail cars	417
Open ,, ...	25
Length of single track in miles	103
Passengers carried by electric cars	7,108,973

This company paid last year a dividend of 5 per cent. Out of a total of 29 million passengers carried on the whole system, over seven millions were carried by electric cars; and whereas a perceptible decrease has taken place both in the passengers carried and receipts on the horse lines, the contrary has been found to be the case on the electric lines, where the number of passengers carried has increased 32 per cent. since the introduction of the electric system, and the electric car receipts have increased 34.9 per cent. The company employs 2,177 persons. The concession has 27 years more to run.

The cars are exceedingly well lighted by means of ten 16 candle-power incandescent lamps. All the motor cars are furnished with "G. E." 800 motors, and the whole system was equipped by the Union Elektricitäts Gesellschaft of Berlin. The tramway company have relaid the whole of their tracks with heavy girder rails weighing 107 lb. per yard.

It has been found that 1.3 kilogrammes (2.866 lb.) of coal is burnt under the boiler for each kilowatt furnished at the switchboard, and 6.2 kilogrammes (13.668 lb.) of water are required per effective horse-power.

The coal burnt is Welsh coal, and costs 18.80 marks (about 18s. 6d.) per ton delivered at the power-house.

Besides the tramway owned by the Hamburg Tramway Company, there is another line owned by a separate company, and which runs from Hamburg to Altona. This line was equipped entirely by Messrs. Schuckert and Co. The cars are very handsome; one of them is shown, Fig. 419. The motors used on these cars have their framework made of cast steel.

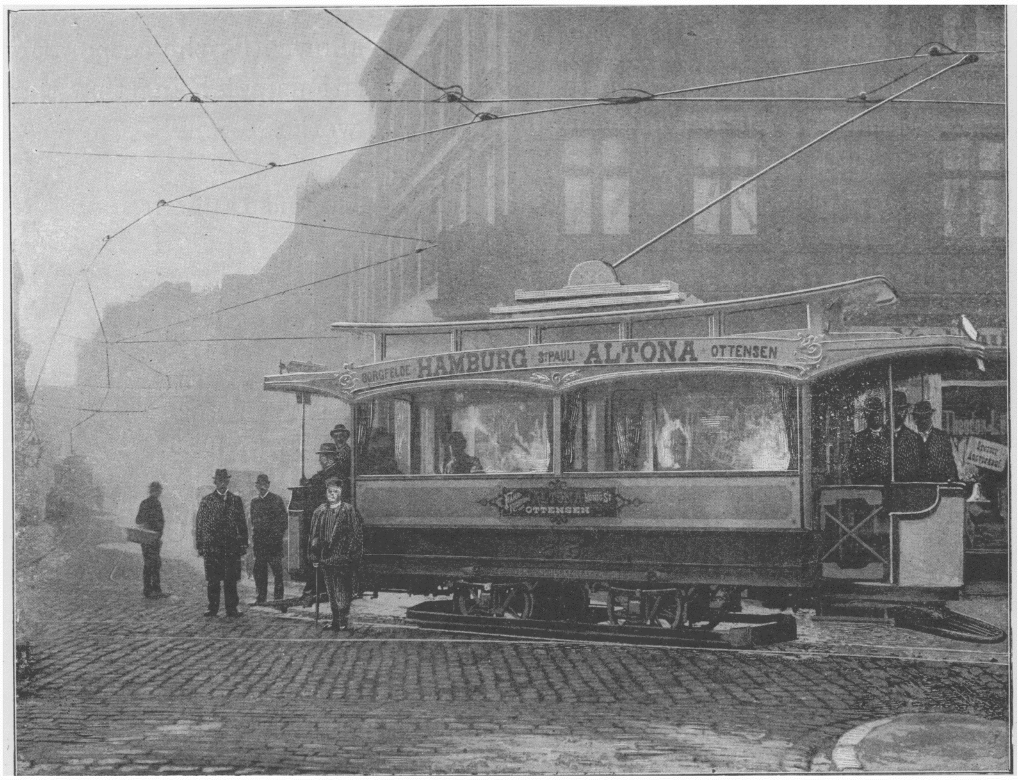


Fig. 419. Car of Hamburg Altona Line.

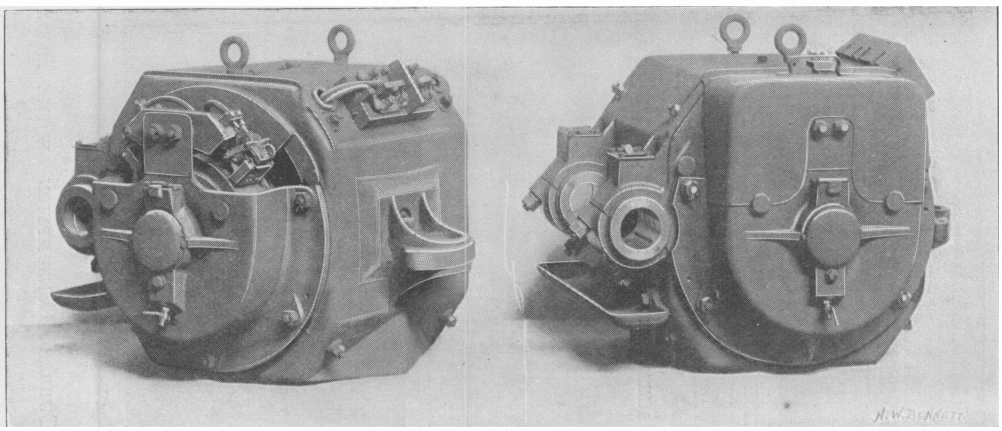
They are of the four-pole type, with Gramme ring armatures, and entirely boxed in. Figs. 420 and 421 are outside views of the motor. Each pole has a magnet winding round it. The armature is wound in 67 sections, each section having 12 turns.

Series parallel controllers are used, which are so arranged as to act as electric brakes when turned backwards, and these are always used, the ordinary hand brake being kept as a reserve. It will be noticed that the bottom of the trolley arm is protected by wooden casing; this is done in

order to avoid short circuits should telephone wires break off and fall across the car roof. The total length of this line is some ten miles. For some miles inside the town these cars pass over the track of the Hamburg tramways, and for the distances run on these lines they have to pay so much per car-mile.

When they get upon their own lines they take current by meter rate, some from the electric supply works already described, and some from the electric works of Altona. This system has given such satisfaction that the Altona Company are now busy transforming all their horse lines into trolley lines.

As a very good example of the second system—that of utilising existing alternate or continuous current installations—Rome may be cited.



FIGS. 420 AND 421. MESSRS. SCHUCKERT AND COMPANY'S RAILWAY MOTOR.

Fig. 422, as illustrating the various demands on the system, for which the writer is indebted to the courtesy of Professor Mengarini, of Rome, is of great interest, and the results there shown do not only apply to the first case above mentioned, but to all. The advantages of a combined light and power plant are conclusively brought out by this diagram.

The energy for lighting Rome is furnished by a station run by water power at Tivoli, twelve miles from the city. During the hours of greatest light consumption, the station of Tivoli does not suffice, and an auxiliary steam plant, situated in Rome, is run in parallel with it. In Fig. 422 the surface A B C D shows the loss of power in the transmission from Tivoli, the surface, B E E_1 E_2 F_2 F_1 F the energy consumed for lighting purposes, and the rectangles B G I M H C the total amount of energy transmitted

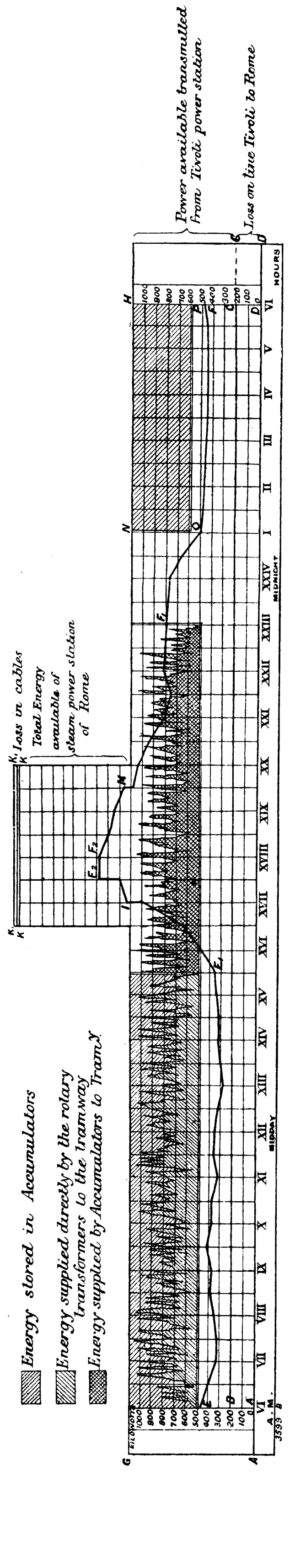


FIG. 422. DIAGRAM OF OUTPUT OF TIVOLI POWER STATION.

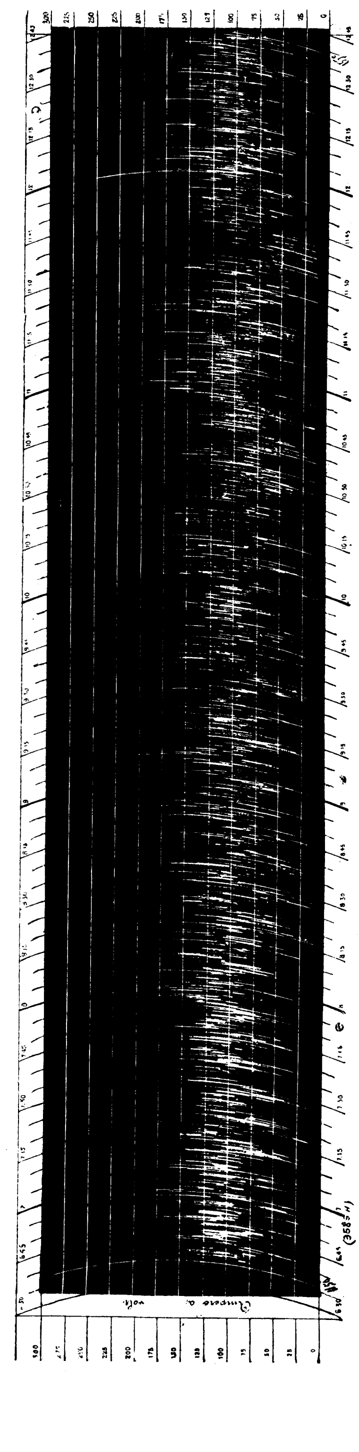


FIG. 423. CURVE GIVING CURRENT CONSUMPTION ON THE ELECTRIC TRAMWAY, ROME.

from Tivoli which is available in the transforming station at Porta Pia. I K K M is the capacity of the auxiliary steam power station in Rome.

The variable amount of load due to a tramway is well shown by Fig. 423, which is the record of part of one day's current consumption as recorded by one of Professor Mengarini's excellent recording ammeters.

About 2,000 horse-power is obtained at Tivoli from a waterfall giving about 825 gallons per second, and with a fall of 160 ft. In this station

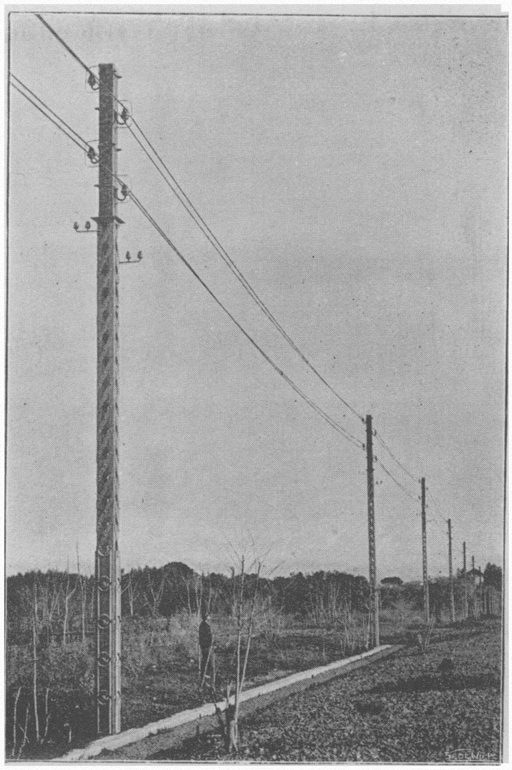


FIG. 424. TIVOLI POWER LINE.

there are six 250 kilowatt alternators directly coupled to turbines and running at 170 revolutions per minute. There are three direct coupled continuous current exciters of 27 kilowatts each, furnishing current at 150 volts. This station was opened on July 4th, 1892. The power is transmitted by four bare copper wires, each one having a sectional area of 100 square millimetres, and supported on oil insulators especially designed for the purpose by Professor Mengarini. Fig. 424, from a photograph, shows the overhead line. The current is transmitted at a pressure of 6,000 volts, and the periodicity of the current is 43 complete cycles per second. At Rome

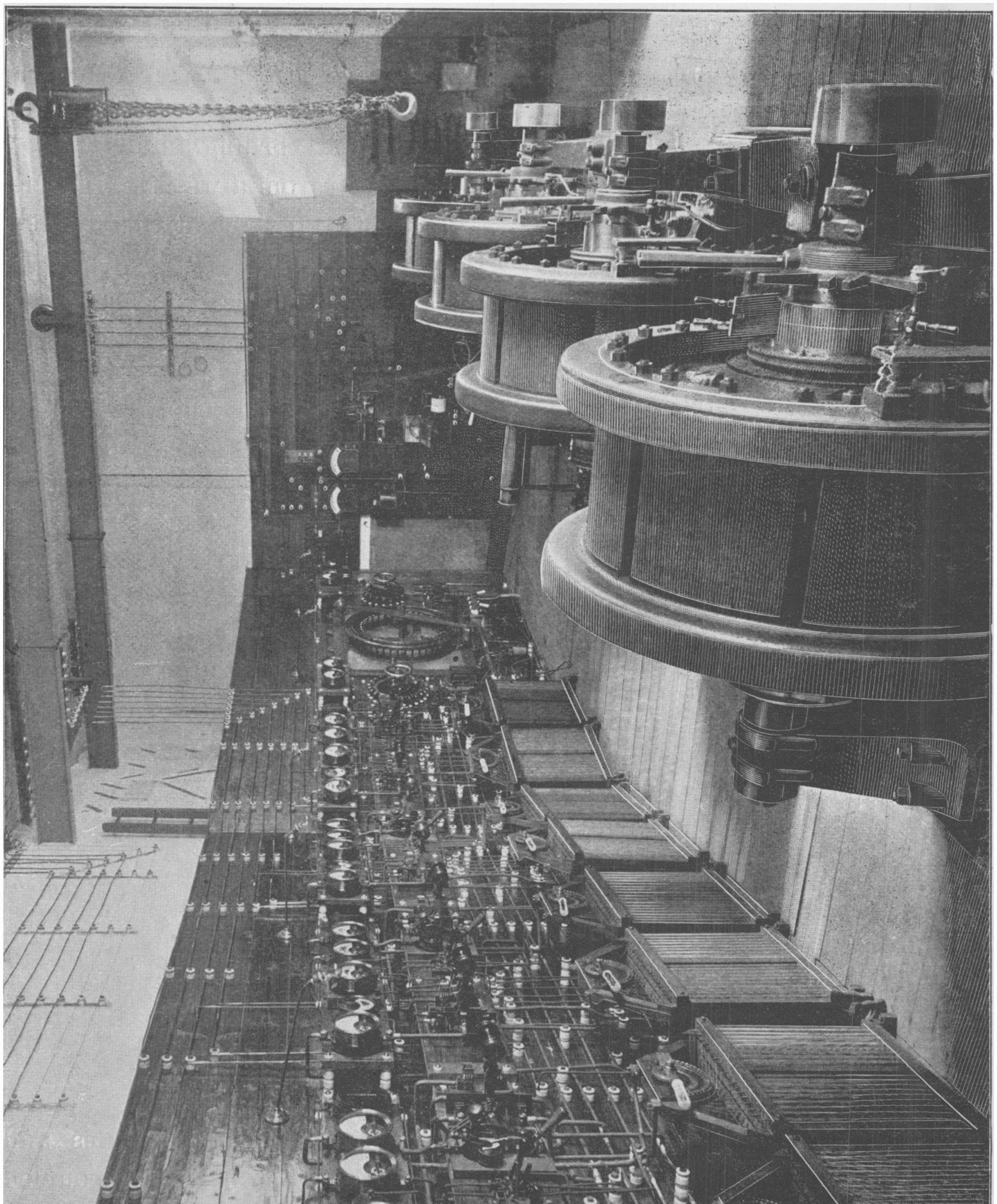


FIG. 425. TRANSFORMING STATION OF PORTA PIA, ROME.

the high-tension current is led into a transforming station situated outside Porta Pia, where the current is transformed down to various pressures, both for incandescent and for series arc lighting. At the station there is a set of transformers which transform the alternating current down to about 400 volts, at which pressure it enters the collecting rings of the rotary transformers. The armatures of these transformers are wound in such a way that on one side the alternating current goes in, and on the other side the continuous current used for railway work is collected at a

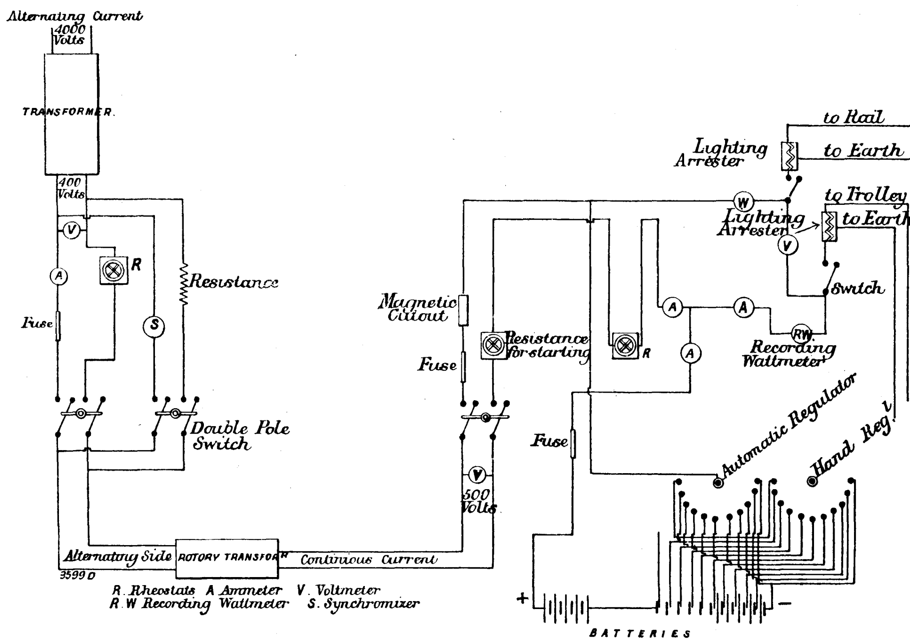


FIG. 426. DIAGRAM OF SWITCHBOARD CONNECTIONS IN THE TRANSFORMING STATION, ROME.

pressure of from 525 to 560 volts. Fig. 425 gives an inside view of the transforming station.

A battery of 304 Tudor cells, and having a capacity of 1,000 ampere-hours, is in parallel with the tramway circuit. Each cell consists of 12 positive and 13 negative plates; 108 of these cells are connected in groups of three to an automatic switch which cuts cells in and out, and maintains the pressure practically constant on the tramway line. The total weight of lead in these batteries is approximately 100 tons. The alternating current motors are excited by a continuous current derived from the accumulators, and 2.5 amperes is required to excite each motor. The continuous current generators are connected to the switchboard in such a way that they can be

connected across any portion of the cells so as to do away with the necessity for an auxiliary dynamo for charging the regulating cells. The automatic regulator which puts the cells in and out of circuit, three at a time, is composed of two solenoids, containing pistons which they suck in or push out as the case may be, and which cause a ratchet to move either one way or the other, according to the direction of the current in the solenoids. The direction of this current is varied by a small switch which is also worked by a solenoid, and which is changed over to the one or the other position, according to the direction of the currents going through it. This current is very small, and its direction is regulated by another solenoid which is wound as a volt-meter, and which is placed on the terminals of the railway circuit. Professor Mengarini has devised an ingenious arrangement whereby the load on the continuous-current generators is always kept constant, whatever the demand of the tramway circuit may be, this demand being equalised by the accumulators. To start up the alternating current motor a continuous current is sent through the commutator on the generating side, and the motor is thus started up and brought into phase. The moment this has taken place the continuous current is switched off, the alternating current is switched on, and the motor then runs at constant speed and the continuous current side can be switched on to the tramway circuit. Fig. 426 shows diagrammatically the switchboard connections. The current is sold to the tramway company at the rate of 1.77d. per

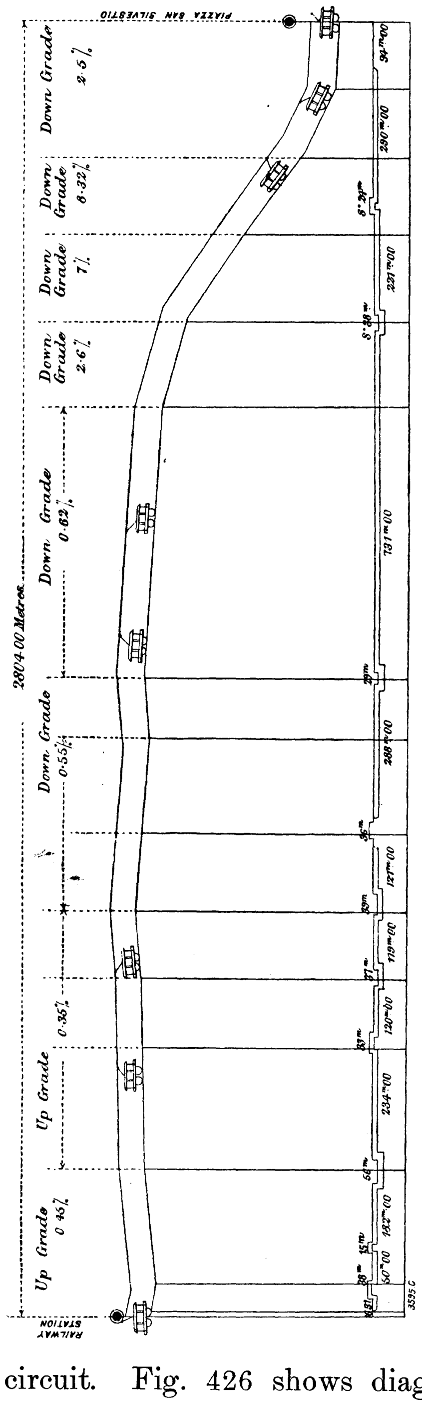


Fig. 427. Longitudinal Section of the Electric Line at Rome.

Board of Trade unit. The electric tramway line at Rome was opened for public traffic on September 19th, 1895, and has been running most successfully ever since. The grades and curves are very severe, as shown in Fig. 427, which gives a longitudinal section of the line. Eight cars suffice to carry the usual traffic, ten, however, being used on Sundays and holidays. Each motor car is fitted with two "G. E. 800" motors, and the track is bonded with "Chicago" rail bonds. The sharpest curve on the line, which has a radius of 24 metres, is situated on a grade of 8.32 per cent. The span wire construction is adopted, the span wire being suspended from rosettes fixed to the sides of the houses. This system is much to be recommended, as it does away with the necessity of all poles. The Roman Tramway Company is so satisfied with the working of this line that it has decided to equip all the remainder of its system with the trolley wire.

The tramways installation at Rome, although at present small, is of great interest, owing to the fact of its being a successful application of ordinary alternating current for supplying power to tramways. The power stations at Tivoli and at Rome, however, were not specially designed with a view to economically supplying current both for lighting and traction. Had this been the case, a different system of alternating current would certainly have been adopted, and there is little doubt but that the three-phase system would have been selected.

The great success of this system is due to the care and foresight of Professor Mengarini, of Rome, who, in connection with Mr. Blathy, of Messrs. Ganz and Co., of Budapest, originally designed and put in this successful plant, and later made it available for running the tramways.

CHAPTER XXVII.

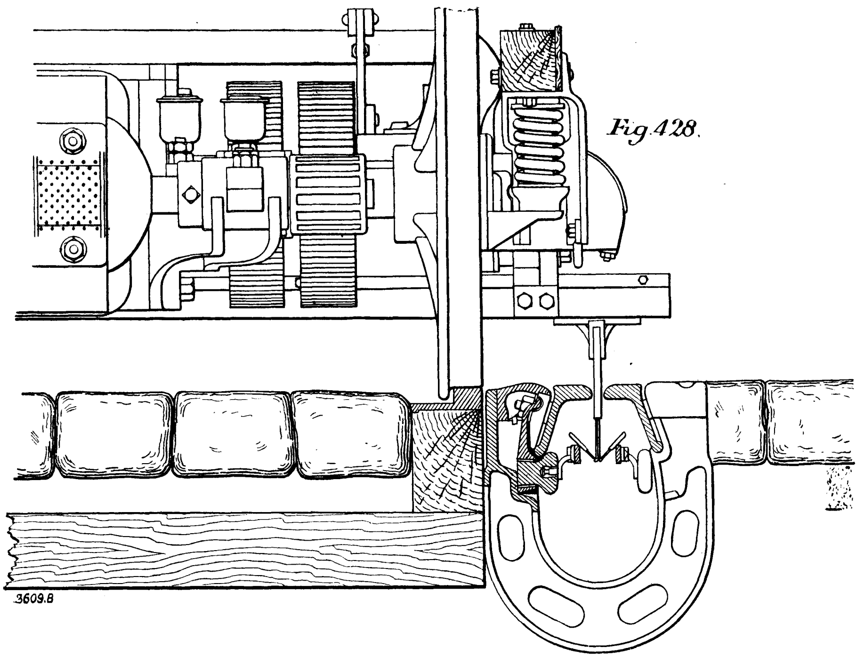
OPEN CONDUIT SYSTEMS.

FROM the very inception of electric traction inventors have been seeking to devise some method of doing away with the necessity for overhead wires. Naturally, the plan of placing the wires in an underground conduit has been the subject of many inventions, and so-called "systems" are numberless. The first attempts were failures, electrically and mechanically, the trouble being that economy in the first cost was necessary to the promoters, and consequently the conduits were much too shallow and badly drained, and would easily fill with snow, mud, and all sorts of detritus, so that short circuits were numerous and excessive leakage of current arose. These early conduits were built without sufficient strength to resist the closing action on the slot, due to frost and other strains which come upon the yokes in practice. No shallow or cheap open slot electrical conduit can ever be successful in northern climates at least.

Within the past few years this has been recognised, and electric conduit construction has more nearly approached the cable system in size and strength of conduit and yokes, so that much better results have been obtained. Complete systems of drainage have been provided, heavy yokes are used, and manholes are frequent; in short, the electric conduits in operation to-day differ little from cable conduits in general construction, though possibly a little less expensive in first cost. The care taken in the construction of these conduits and the perfection of drainage and cleaning are such that much confidence is felt by engineers in the results which will be obtained.

The problem is less one of invention than of skilful mechanical engineering. Those who are most interested in electric conduit construction admit that its first cost is such that it will be impossible for any except the great metropolitan roads to adopt it, for it must be remembered that the expensive feature of the cable system—the cable conduit itself—is joined to the most expensive feature of the electric system—the motors and power plant thus making up a combined system far more expensive than either alone.

But the open conduit system is not the only solution of the problem. Much inventive ability has been devoted to the production of several closed conduit systems differing more or less in detail, but much the same in general principles. In these systems the conduits are simply tubes carrying the feed wires and the main conductor, all carefully imbedded in solid insulating material. These tubes are connected to junction-boxes at short intervals, in which are placed electro-magnetic or mechanical apparatus, which complete the electrical connection between the main conductor in



BENTLY KNIGHT CONDUIT; CROSS SECTION IN PAVED STREET. Concrete Conduit.

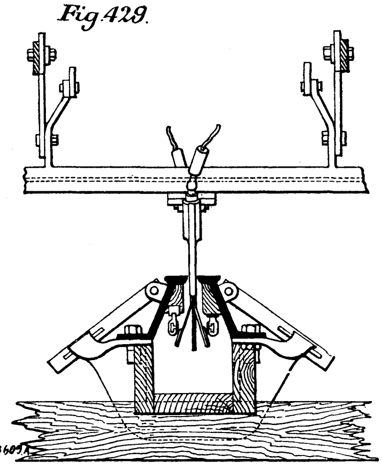
the tubes and a series of contact pieces slightly raised above the surface of the ground, whenever the car passes over these contacts. A long shoe carried by the car makes connection between the contact pieces and the motors, and power is thus obtained for the propulsion of the car.

Theoretically, this system has many great advantages, not the least of which are cheapness of construction, apparent simplicity, and, of course, the avoidance of overhead wires. One of the faults is the difficulty of keeping the apparatus in the junction-boxes in proper working order—some 500 sets of these being required per mile of track. This difficulty is partially met by the fact that the sliding shoe of the car will touch two of

the contact pieces, and the chances of both being inoperative are comparatively small. Another possibility of trouble lies in the fact that if leakage of current should at any time be set up in any of the moving parts, or between the contacts, or if the magnet armatures should stick on closed circuit, there might be trouble, either from short-circuiting or from shocks to horses and people.

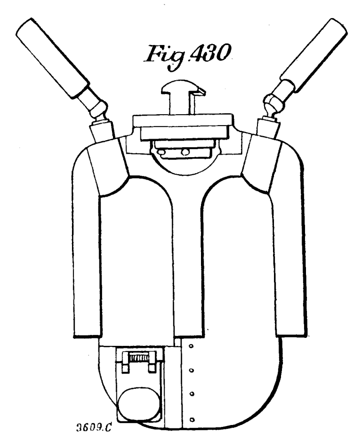
When electric traction was first introduced, overhead wires were looked upon by many as an obstacle to its extensive introduction, its great advantages not having at that time been realised. In 1884 the Bentley-Knight Electric Railway Company opened a conduit electric railway in

Fig. 429.



Bently Knight Conduit; Cross Section. Wooden Conduit.

Fig. 430



Bently Knight Conduit Plough.

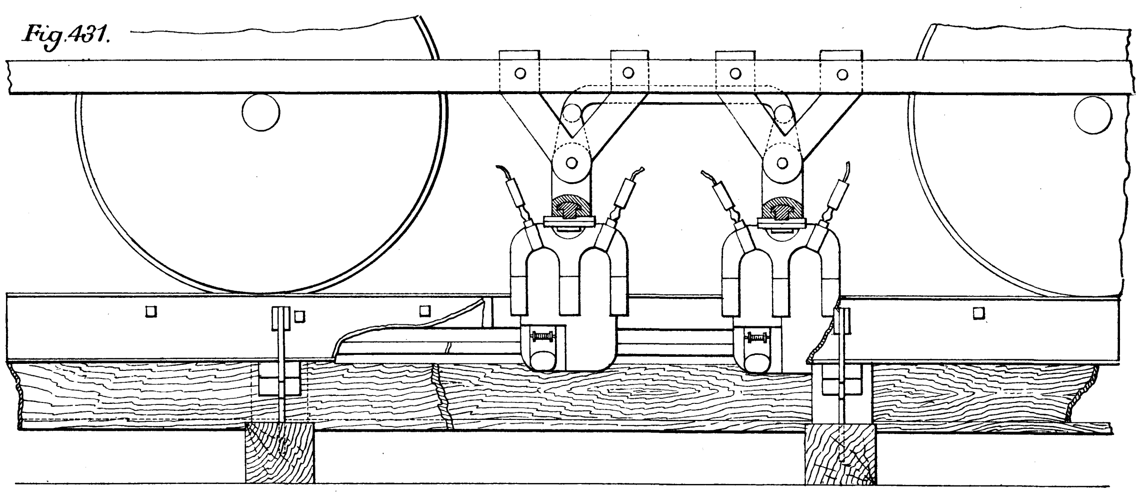
Cleveland, Ohio, another in 1888 in Allegheny City, Pa., and another in 1889 at Boston, Mass.

In constructing, Figs. 428 and 429, the iron yokes were set up from 4 ft. to 6 ft. apart, and the conductors set against the insulators which supported them at each yoke, The electrical connections between lengths of conductor were then made, the slot-steels set on the yokes, and the slot-steels and bolts firmly bolted together, leaving a slot opening at the surface of the street of $\frac{5}{8}$ in. The width of the slot could be regulated, the slot rails removed, and the conductors, insulators, and interior of the conduit inspected and repaired, in case of need, without disturbing the pavement. The conductors were copper bars connected by expansion joints, and were $1\frac{1}{2}$ in. wide by $\frac{3}{8}$ in. thick. Neither the rails nor the conduit itself formed

any part of the electrical circuit. The total excavation for the heaviest conduit was 18 in. in depth by 16 in. in width.

Electrical connection between the motor and the conductors in the conduit was effected by contact ploughs (Figs. 430 and 431), consisting of flat frames, hung from the car by transverse guides (on which they were free to slide the whole width of the car), and extending thence down through the slot of the conduit. These ploughs were so constructed as to adjust themselves to all inequalities of road or conduit The frames carried and protected flat insulated conductor cores, to the lower ends of which were attached small contact shoes, which slid along in contact with the conductors in the conduit. At the upper ends of the ploughs were

Fig. 431.

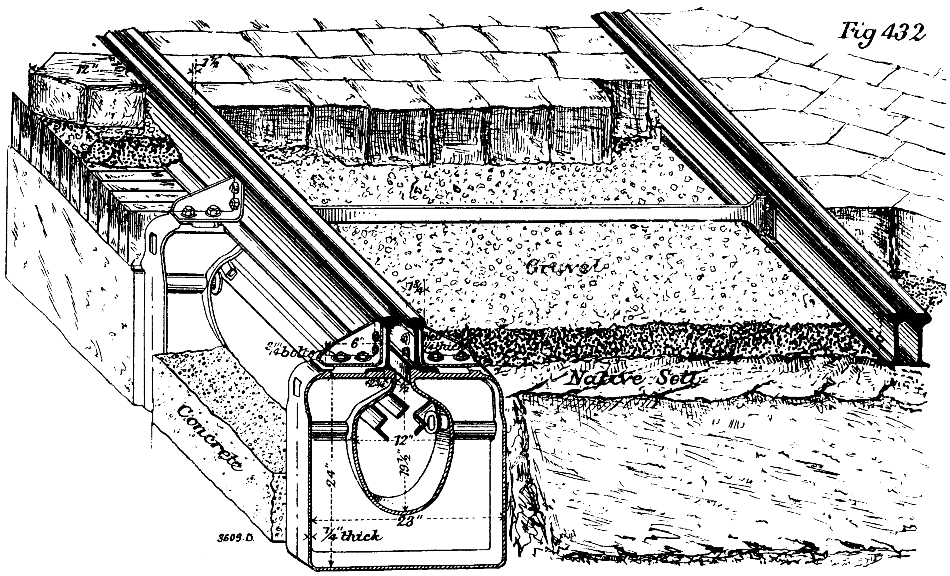


BENTLY KNIGHT CONDUIT; LONGITUDINAL SECTION, SHOWING PLOUGHS.

attached connections leading to the motor. The ploughs could be inserted or withdrawn through the slot at will, spring connections allowing the contact shoes to straighten out into line with the conductor cores when the plough was pulled upward. The plough guides were hung on transverse axes, and were held in a vertical position by a catch, which gave way when a plough met an irremovable obstruction, allowing it to be thrown completely out of the conduit without injury, it being also immediately replaceable. The frames of the ploughs had wearing guards of hardened steel wherever they touched the edge of the conduit slot, and the shoes were made of soft metal which took up the wear and prevented injury to the conductors. Two ploughs were used on each car for the sake of absolute reliability.

In general principle the design of the Bentley-Knight Company has been followed by all others which have attempted to solve the conduit problem. That it was the pioneer in sub-surface conductor work is unquestionable, but it was many years before its time. With the enormous demand for trolley-line equipments, great improvements were made in insulating material, &c., and those who have most lately taken up conduit work have had at their disposal appliances which rendered it easy to surmount difficulties which in earlier days were practically insuperable.

The Siemens Conduit at Budapest.—Budapest was the first Continental city to adopt a conduit system. The first line in this city was opened in



BUDAPEST CONDUIT.

1889, and was designed and constructed by Messrs. Siemens and Halske, of Berlin. At Budapest the channel is under one of the rails, and not in the centre of the road as usual (Fig. 432). The conduit consists of castings having flanges 18 centimetres (7 in.) placed every 1.2 metres (about 4 ft.), the space between forming a concrete conduit. The oval-shaped conduit has a clear width of 28 centimetres (11 in.) and a height of 33 centimetres (13 in.). The slot consists of two girder rails without inside flanges, and they are fastened to the conduit frame by wrought-iron angle-pieces. The width of the slot is nominally 33 millimetres ($1\frac{5}{16}$ in.) The total depth of the foundation below the rail top is 70 centimetres ($27\frac{1}{2}$ in.). The conductors, both positive and negative, are made of angle-irons, secured

by means of insulators fastened to the castings. They are sufficiently high above the bottom of the conduit, it is claimed, to be protected from the water collecting in the conduits, and are under cover, so that they cannot be harmed by anything falling through the slot. The water from the conduit is collected at the lowest points into settling-boxes, from where it passes into sewers. The conductors are joined at intervals to feeders. The feeders are lead-covered armourclad cables laid directly in the ground.

The cost of track and conduit at Budapest per mile of single track was £7,000 approximately, and of this track construction alone without conduit came to about £1,500.

As will be seen from the foregoing description, the circuit is double, and there is no return by the rails. Although the nominal width of the slot is 1½ in., at points and crossings this width often exceeds 2 in. The pressure used on this line is 300 volts.

Holroyd Smith's Conduit at Blackpool.—At Blackpool a conduit line designed and constructed by Mr. Holroyd Smith is running, using the rails for the return circuit. It is one of the earliest examples of English electric tramways.

The conductors consist of two semicircular channels of copper supported by insulators from cast-iron chairs. The conductor is split into two parts. The collector is formed by a steel frame passing through the slot, and having contacts sliding on the underground conductor. The contacts are insulated from the steel frame, and communicate with a clip terminal on the car by means of an insulated cable. Light leather straps serve to draw the collector along the slot. Should the collector be stopped by an obstruction, the leather straps break, the insulated cable slips out of the clip, the current is interrupted, and the car comes to a standstill.

The chairs supporting the sides of the conduit are of cast iron, 11 in. high, with a 12½-in. base and internal width of 5½ in. The bottom is rounded, and the ends have pockets for holding the side boards. These chairs are placed every yard, and support the steel troughing, which is bolted to their surface. The nuts are covered and locked by a cast-iron cap. The troughing is filled with wooden blocks. The troughings are inclined inwards, so that any object having passed the slot will not stick, but fall right through. The space between them at top is ½ in. and at the bottom 1 in. The sides are formed of creosoted wood. A 2½-in. hole is bored midway between the chairs, in which the porcelain insulator is fixed. A ¾-in. hole is bored at right angles to the first, through which a wooden peg

passing through the groove of the insulator locks it fast. The roadway under the side pieces is packed; the centre is concrete, and tooled to form the same curvature as the bottom of the chair.

The conductors are of hard-drawn copper, in lengths of 36 ft. and weigh 11 lb. per foot. The conductors are placed at an angle for convenience in fixing, and in order that the collector may partially rest on them. The copper tubes are connected one with the other by brass wedges exactly fitting inside the tube; space being left between the ends to allow for expansion and contraction. The two tubes are electrically connected every 100 yards by U-shaped loops of insulated and lead-sheathed copper wire placed in grooves cut in the sides and bottom of the channel. Over each of the loops is a handhole, made by cutting both the steel troughs and filling the place with two pieces 1 yard long. These handholes are needed for the insertion of scrapers for cleaning the channel and for removing collectors. Only the positive poles of the dynamos are in communication with the conductors, the return being by the rails.

The collector consists of a centrepiece and two cleaning ploughs. The ploughs are joined to the collector by a tempered steel strip or a hinged wrought-iron plate. The tempered steel plates forming the ploughs are held by cast-iron cheeks, and are placed at an angle. Their upper ends terminate in a prong, to which is attached the ring of the hauling rope. The centrepiece, or collecting plough, is of cast iron, and holds a plate of strong brass, thoroughly insulated and protected by hardened steel guards, where it passes through the troughing. The bottom of this plate is bared, and has attached on either side a short plate of brass or wire forming a T, and holding at either end hard metal rings.

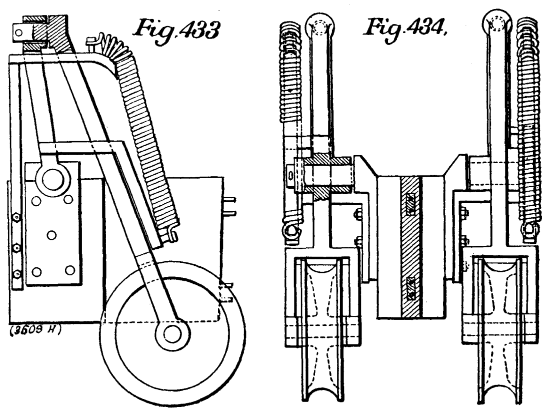
The Waller-Manville Conduit.—Messrs. Waller and Manville have developed a system which permits of the conductor being put in and withdrawn from the conduit through the slot, thus obviating the necessity of breaking up the road when the conductor wants repairing or looking to. Its essential features are mechanical devices, permitting a flexible conductor to be used. The conductor being flexible, the supports can be placed at long intervals and in side openings to the conduit itself on large insulators.

Removable covers are provided to the hatchways, giving access to the insulators. In sharp curves, where it is necessary to attach the conductor to its support, freedom in upward movement is allowed. A constant strain is maintained upon the conductor by automatic apparatus at intervals. The

collector is U-shaped, the conductor running in it. The collector lifts the conductor off the ordinary supports during its travel, and in case of those supports to which the conductor is fixed, lifts the supports themselves.

The Love Conduit at Washington.—The oldest conduit line which is still running in America is that constructed on the Love system, and now in operation at Washington.

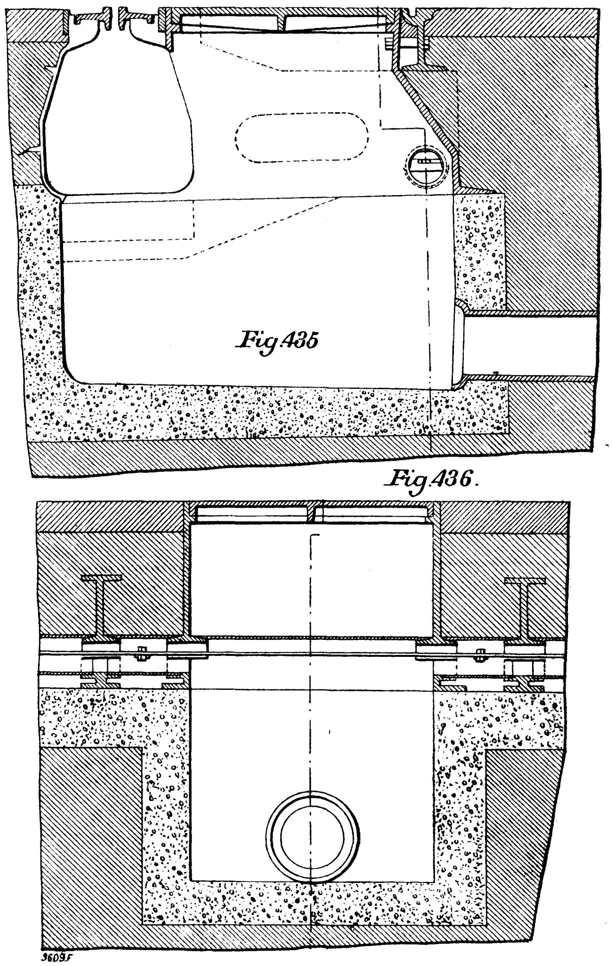
The conduit system of Mr. Love consists in replacing the overhead trolley by a pendant bar—similar to a cable grip-bar—carried below the car and working through a slot in the top of the conduit in the centre of the tramway track, this pendant bar carrying at its lower end a double trolley, with wheel rolling contacts, Figs. 433 and 434, which press upwards against bare copper conductors, carried on insulators in the conduit.



CONTACT WHEELS; LOVE CONDUIT.

Figs. 435 and 436 are cross-sections through the manholes located at suitable intervals. The depth excavated below the road level is 2 ft. The slot rails are in 32-ft. lengths, and bolted to the yokes every 4 ft. Pockets, or small handholes, are provided in the road over every bolt, so that, if required, the rails can quickly be removed, and the conductors and insulators exposed to view. The slot rails are spaced for a $\frac{5}{8}$ in. slot, and shaped with 5 in. inside lips, so as to shed water into the conduit clear of the wires. The track rails are held by claw bolts to the yokes, as shown, and the whole construction rests on a bed of 6 in. concrete, and is packed round with concrete as a bed for the stone blocks of the roadway. In the webs of the yokes spaces are left for laying pipes to contain feeder wires (Figs. 437, 438, and 439), the conductors being in sections of 500 ft. The

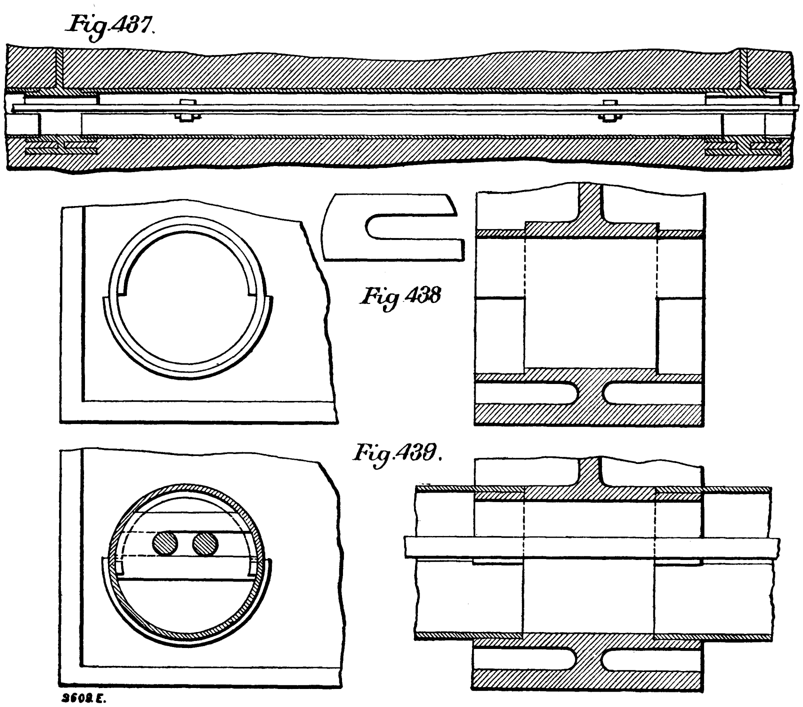
conductors are bare copper wires or rods, nearly $\frac{1}{2}$ in. in diameter, and suspended from loose-fitting gun-metal clips, or ears, as shown (Fig. 440). The stalk of each clip is secured to a block of insulating material, which is suspended from two shoulder bolts bolted to the yoke. To allow for expansion of the conductors, the blocks are free to move about $2\frac{1}{2}$ in. on the



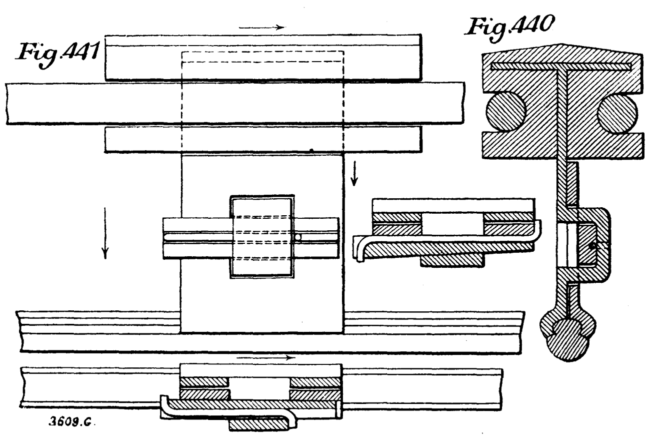
MANHOLE SECTIONS; LOVE CONDUIT.

rods. With the trolley wheels travelling in the direction of the arrow, it was found that the blocks shifted a little in the reverse direction every time the trolley wheels passed, and it was necessary to put stops (Fig. 441). The insulators are fixed to every alternate yoke, at a distance apart of 9 ft. on the straight run. On curves, however, they are closer together, and stronger supports are used, the conductor being circular in section, and

clipped in ears having circular jaws. Fig. 442 is a cross section through the conduit, and shows the conductors in position.



LOVE CONDUIT PIPES FOR CARRYING FEEDERS.

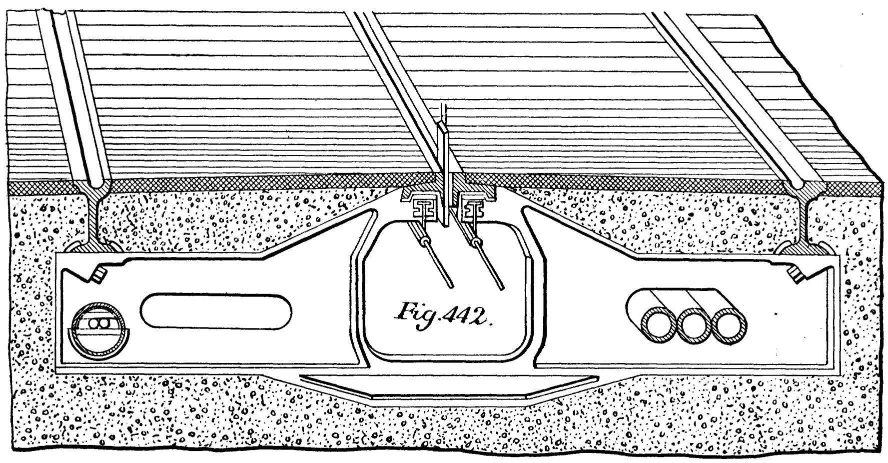


LOVE CONDUIT; MODE OF SUSPENDING CONDUCTOR.

The trolley wheels bear upwards on the underneath side of the conductor. The illustrations, Figs. 443 and 444, show the arrangement with spring for keeping tension on trolley wire. The plate travelling in

the slot and supporting this gear is of $\frac{1}{2}$-in. steel, and $4\frac{1}{2}$ in. wide. The trolley arms are jointed to take lateral as well as vertical movement, and thus follow every change of direction of the conductors.

The first employment of this system of Mr. Love was at Chicago at the time of the great Exhibition in 1893. The line consisted only of a loop



LOVE CONDUIT; CROSS SECTION.

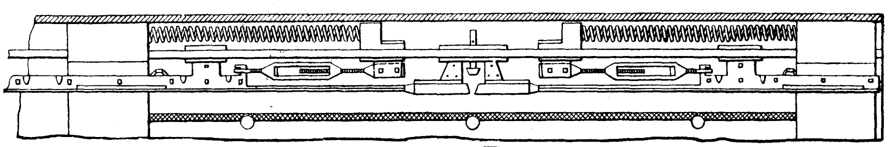
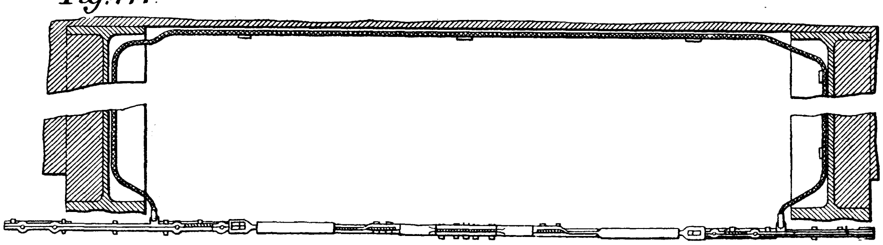


Fig 443

Fig. 444.



TENSION ARRANGEMENT FOR TROLLEY WIRE.

forming the junction between the up and down tracks of an existing tramway. A specially designed electric motor-car was provided with a pendant grip-bar supporting a flexible double trolley, with wheels running in contact with the underside of two bare conductors, carried by insulators in a conduit in the centre of the track, and the ordinary cars were towed by this motor-car round the loop.

The second installation was at Washington. This was put into use on March 3, 1893, and has been continuously at work since. It consists of the inner or town end of an ordinary electric line running out about seven miles into the country outside the city boundary. The length is $1\frac{1}{4}$ miles. Outside the city boundary, overhead wires and trolleys are used. At the junction of the trolley wire and conduit sections, which is on a slight incline, there is a manhole in the centre of each track leading to a vault. A car is run over the chamber, the overhead trolley is hauled down so as to lie flat upon the top of the car, the grip-bar is attached to the car by a man in the vault, and the car continues its journey. The time taken in changing over is about 15 seconds. The junction of the two systems occurs at a regular stopping-place, and no running time is lost. A separate generating station is used for each portion of the line. A third installation is now being laid down in Amsterdam Avenue, New York.

The General Electric Company's Conduit as laid in Lenox Avenue, New York.—One of the most recent and best laid conduits is that of Lenox Avenue Line, New York, constructed by the General Electric Company of America. The railway company which owns the line has had the conduit so constructed that, should electricity fail to give satisfaction, it could be used without modification as a cable line. This line has run through one winter, and it is understood to have given satisfaction. It is double track. The district served is somewhat sparsely settled, but added transit facilities will probably result in rapid development.

The construction is very simple (see Figs. 445 to 450). A plough suspended from the crossbar of the car truck passes through the slot in the centre of the track, and presses against the flat surfaces of two iron conductors running the entire length of the conduit. These conductors are placed on each side 3 in. off the centre line of the slot to avoid the drip, and are of channel iron, weighing about 21 lb. to the yard, 4 in. deep, and 30 ft. lengths. They are suspended for most of the way from the yoke by insulators devised for this especial purpose, and are 13 in. below the conduit slot. Each insulator is held in a cast-iron bracket, into which is tapped a bolt (Fig. 445). The shank of this bolt is surrounded by insulating composition to a thickness of about $\frac{1}{4}$ in. Surrounding this is $1\frac{1}{16}$ in. of mica, and around this $\frac{3}{8}$ in. porcelain or insulating compound, both of which are now being tried. The head of the bolt is surrounded by an insulating compound in the socket in which it is imbedded. The socket is fastened to the slot rails by two bolts.

The insulators are set every 15 ft., one at each of the manholes, which are 30 ft. apart on straight track, and one at each of the handholes, which are midway between the manholes. The insulators at the handholes are the same as those at the manholes, but the method of attachment is

Fig. 445.

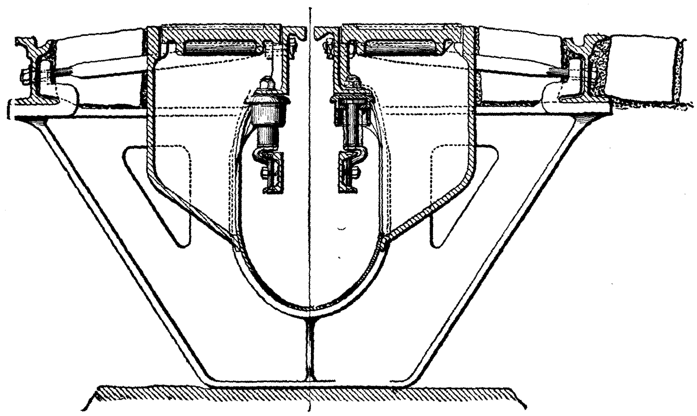
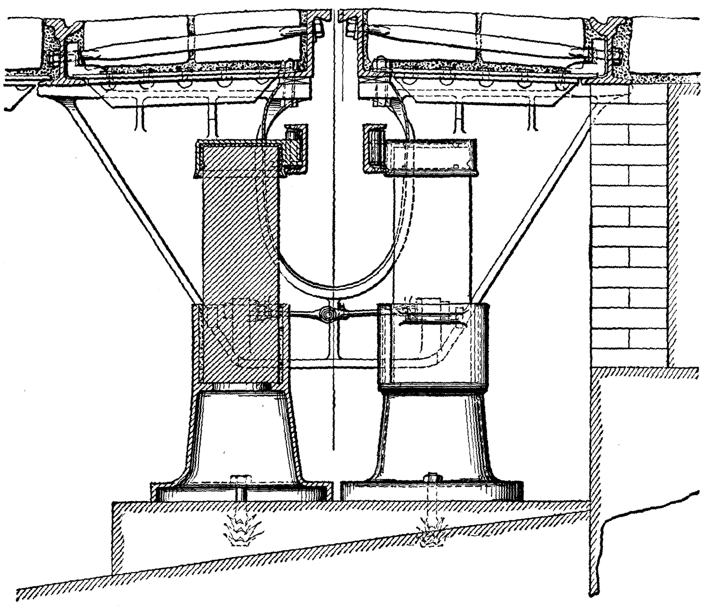


Fig. 446.

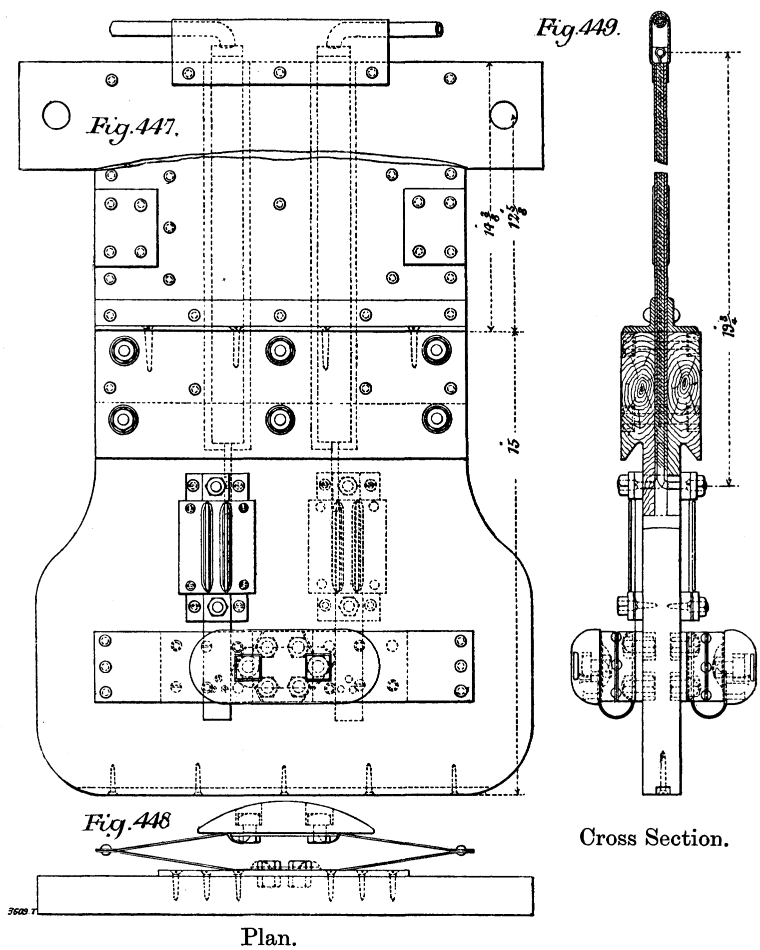


Cross Section through Conduit; Lenox Avenue.

slightly different. The conductors are bonded to each other by copper wire securely riveted into the web of the metal. A modification of this system of suspension is introduced for about 100 yards of single track. This is known as the pedestal method of support (see Fig. 446). At the

manholes, instead of insulators suspended from the ceiling of the conduit, the conductors are supported by a soapstone pillar. The channel bar conductors in this case are 5 in. deep, and are set 12 in. below the slot. The soapstone pillars are provided with iron caps furnished with brackets to which the conductors are bolted, and continuous connection is secured by

Side Elevation.



Cross Section.

Plan.

CONDUIT PLOUGH; LENOX AVENUE.

means of a bond of flat copper strips riveted to the web. The soapstone blocks are set in iron bases erected in the manholes.

Every twelfth manhole is connected with the power-house by telephone. Quick break switches are placed at intervals in these manholes, in order that any section of the line may be cut out in case of trouble or accident. At track points each conductor is provided with a flaring nose

to facilitate the entrance of the plough into the conductors. The manholes are 4 ft. 4 in. in depth, 4 ft. in length, and 14 ft. $5\frac{1}{2}$ in. in width, that is to say, the entire width of the tracks. They are of brick, with 8-in. walls resting on concrete foundations. The floors are laid with 6 inches of concrete, and are provided with drains for carrying off the water.

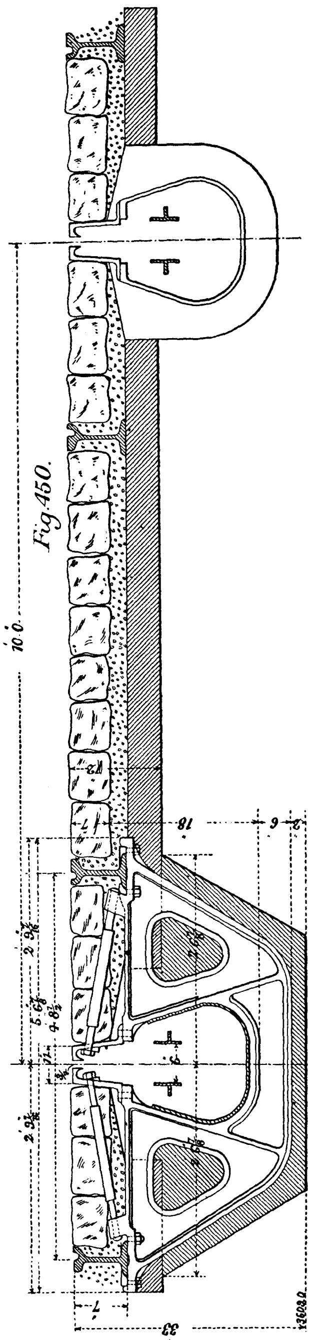


Fig. 450.

METROPOLITAN RAILWAY CONDUIT, WASHINGTON.

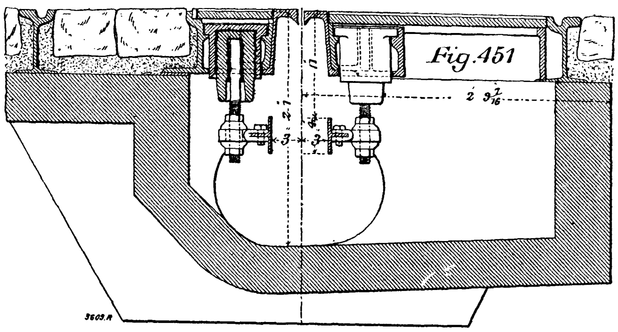
The conduit was built along the grade of the street, but with sufficient pitch to permit water to find its way to the manholes and thence into the sewers. Each conductor forms one side of the working circuit.

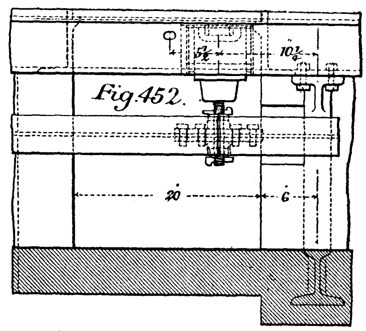
The contact-pieces of the plough, Figs. 447 to 449, are of cast iron, and are supported on spring leaves, which cause them to press outwardly against the two conductors, at a tension of not over 6 lb. The conductors, which are of sheet copper taped, are brought up to the car, and are protected on each side as they pass through the slot by sheet steel. A heavy sheet of fibre is between the contact shoes to prevent arcing.

The Metropolitan Railway Company's Conduit Road, Washington.—Another line which has been working for some months successfully is that belonging to the Metropolitan Railroad Company of Washington. The conduit was designed by Mr. A. N. Connett. As will be seen from Fig. 450, it is practically identical with cable tramway practice, great care having been taken to make it strong enough to resist strains and variations of temperature.

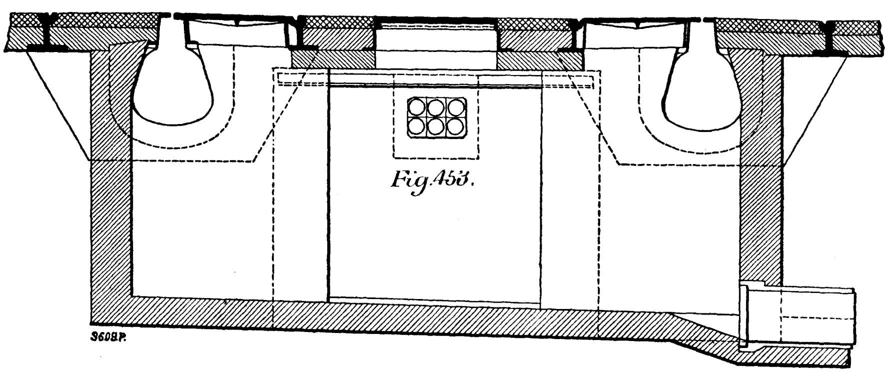
The slot rail is the same as used on cable lines, with the exception of the water drip at the edge of the slot; it weighs 67 lb. to the yard. The grooved track rail is 7 in. deep, and weighs 83 lb. to the yard. The guard rail is the same depth and takes the same splice-bar; its weight is 87 lb. to the yard. The splice bars

are 30 in. long, $\frac{9}{16}$ in. thick, and bolted on with six 1 in. bolts. The yokes weigh 267 lb. Their depth from grade is 31 in. The inside depth of the tube is 25 in. Every $13\frac{1}{2}$ ft. there is a large manhole frame and cover (see Figs. 451 and 452) extending from track to slot rail, and 20 in. wide; opposite this is placed a small frame and cover just sufficiently large to hold an insulator. The corner of the large frame is arranged to take the opposite insulator. The insulators in this way are clear from and entirely independent of the yokes.





METROPOLITAN RAILWAY MANHOLE.



METROPOLITAN RAILWAY MANHOLE DRAINAGE.

The conduit is formed entirely of Portland cement concrete. The entire width of the tracks to 2 ft. outside of the outer rails rests on a concrete paving base. The insulator is large, being 4 in. in diameter and $7\frac{1}{2}$ in. deep over all. It is held in an iron cap, and supports a bolt by having the corrugations filled in with neat Portland cement. The drawings show this clearly. The cement has proved satisfactory, and the assembled insulator seems to be abundantly strong mechanically for the rough usage to which it may be subjected. A malleable iron clip is held by nuts to the

insulator bolt, and the clip in turn supports the conductor rail as shown. Adjustment in a direction at right angles to the slot is provided for in the clip where the insulator bolt is held, while in a direction parallel to the slot the adjustment is made in the seat of the insulator case on the frame. The conductor rail is mild steel. It is a T-section, weighing $23\frac{1}{2}$ lb. to the yard. Its equivalent section in copper is assumed to be 300,000 circular mils. One-half of the road is double, and the remaining half single bonded with Chicago rail bonds. The circuit being made on the insulated conductor rails, the track rails are not bonded. Hatches are provided every 400 ft. by which the conductor rails, 27 ft. long, can be placed in the tube after it is finished.

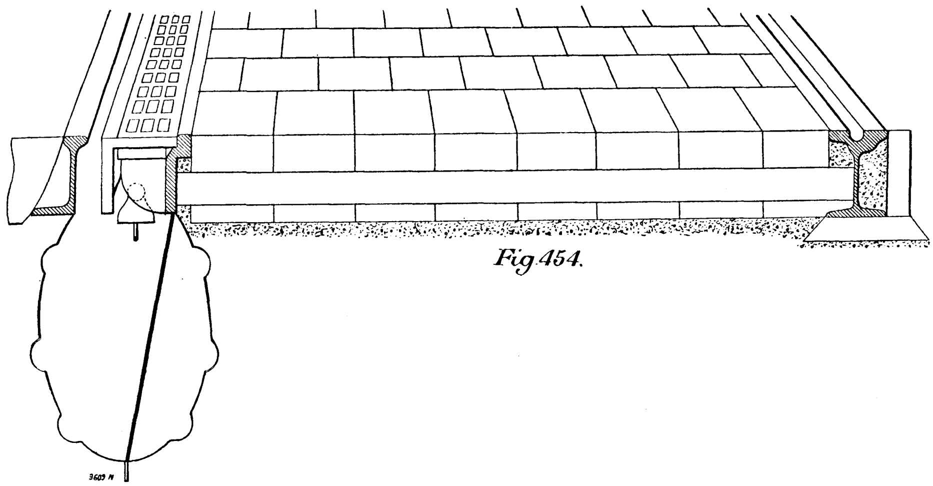


Fig. 454.

DRESDEN CONDUIT.

Fig. 453 shows the method of track drainage used where the duct manholes are between the tracks; where they are on one side the tracks are connected by large sewer pipes to these manholes, from which connection is made to the sewer. The tracks are drained in this manner about every 400 ft.

Conduit at Dresden.—Fig. 454 shows a section of the conduit experimentally laid down in Dresden. The local authorities would not allow the trolley wire in one or two streets, hence there is a conduit in one section and accumulator cars in another. This conduit is lined throughout with iron sheeting surrounded with concrete. Cast-iron yokes are set about every 4 ft. The conductors, the bottom and sides of the conduit can be reached at once, without the necessity of taking up the roadway or having manholes.

As will be seen from the cross-section given, one side of the slot is formed by the rail on which the car runs, while the other is formed by corrugated cast-iron plates supported from brackets fixed to the yokes, and which also serve to hold the insulators supporting the conductors. The width of the slot is never less than 1 in., and at points and crossings increases to 2 in. The slot is rather irregular, owing to the cast-iron plates occasionally shifting.

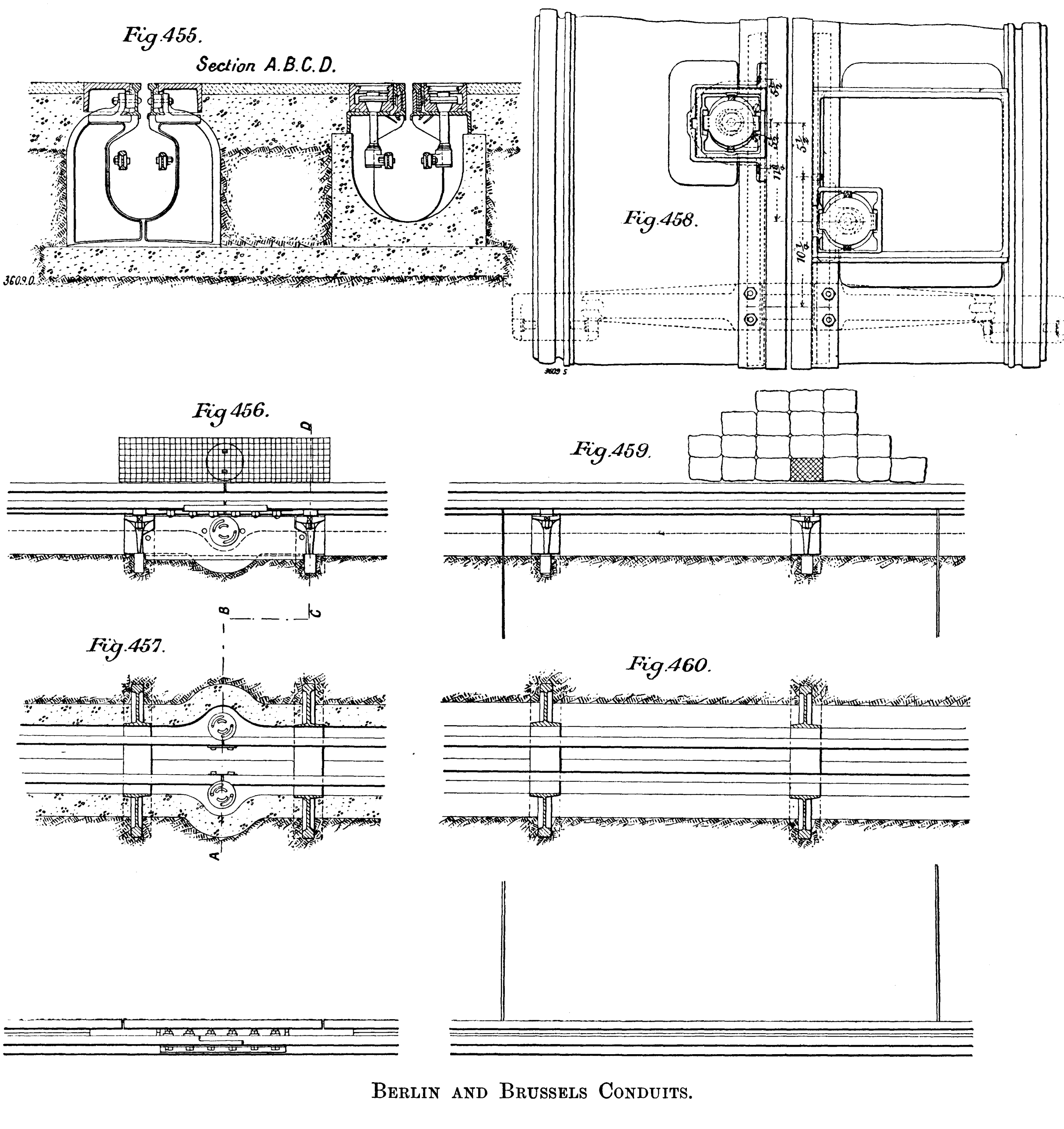
Conduit Designed by the "Union" of Berlin, and now being Laid at Berlin and Brussels.—By the courtesy of the Union Company of Berlin (Thomson-Houston) we are enabled to give a fully illustrated description of this conduit. It is a modified form of that designed by the General Electric Company of America, and laid in Lenox Avenue, New York, which has already been described. The chief difference consists in that instead of having a special slot in the centre of the track, the conduit is built under the line of rails. Figs. 455, 456 and 457 show how the conductors are suspended. These are steel of **I** section and about 25 ft. (8 metres) in length. The yokes are cast iron, and are set on a concrete foundation 15 centimetres thick (about 6 in.), and 1.20 metres between centres (approximately 4 ft.). The width of the slot is 30 millimetres (1.18 in.). On the slot side of the track two **T**-rails are fixed to form the slot, and weigh 52 lb. per yard each. They are supported by the top of the yokes and bolted to them.

Fig. 455 is a section showing the conductors in position. The insulators are located between two yokes, and supported in a cast-iron box with a removable cover (Figs. 456 to 458) which makes them accessible from the roadway. To prevent water getting to the insulators, they are protected by metal caps shown in the section (Fig. 461). The insulators are fixed in the cast-iron boxes in such a way that after a couple of screws have been taken out, by giving the insulator half a turn, it can be removed.

Figs. 454 to 460 are plans of the track; one of these (Fig. 459) shows how, where the streets are paved with setts, the top of the yokes are protected by cast-iron caps.

Figs. 461 to 463 are sections and plan of a drainage pit and manhole. These are put in every 40 metres (approximately 131 ft.), and connected to the drains. A trap is arranged so as not to allow water to flow back from the drains into the conduit, a pit being also provided to collect the mud. This conduit is one of the best and most recent examples of European work, besides which it embodies all that American practice has shown to be most essential in such work. For English practice some modifications would,

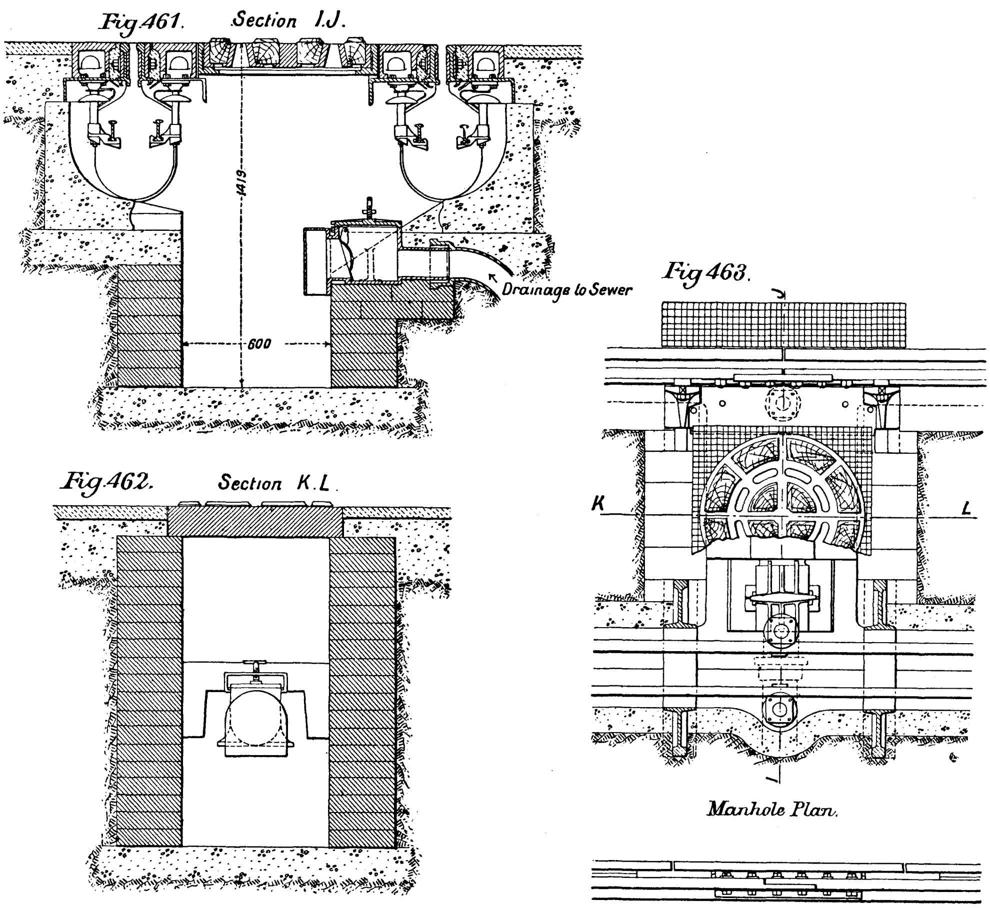
however, be necessary, as it is certain that a slot 1 in. in width would not be tolerated.



Berlin and Brussels Conduits.

General Remarks on Open Conduits.—That it is possible to successfully operate conduit electric roads there is no doubt. But as compared to the overhead trolley system they have several disadvantages. The first

and greatest of these, and the one which more than all others has prevented their general adoption, is the very heavy initial capital expenditure which they entail, an outlay which, by the way, it is very difficult to determine except when all the special conditions of each individual case are known. In towns where water and gas pipes, sewers and drains, telephone, telegraph, and electric light wires are crowded under the paving, a conduit may cost



Berlin and Brussels Conduits.

up to any amount. The writer has in mind one instance in America, where, to enable a conduit to be laid, the whole sewerage system of a town had to be practically relaid. Even supposing fairly favourable conditions, Tables C. and CI. show the probable minimum sum for which a conduit line could be constructed in England or America.

Another great disadvantage of the conduit as compared with the overhead system lies in the fact that should anything go wrong with the

TABLE C.—Giving Approximate Cost of Conduit with Double Conductor per Single Mile of Track as Proposed in England; Slot under Rail.

	£	s.	d.
Excavation … … … … … …	217	6	0
Cement … … … … … … …	645	0	0
Granite paving laid … … … … …	1,760	0	0
Creosoted blocks … … … … …	52	16	0
Stoneware pipe … … … … … …	88	0	0
Steel girder tramway rails … … … …	324	2	2
Wrought-iron fishplates … … … …	6	18	2
Bolts and nuts … … … … … …	3	15	0
Tie-bars … … … … … … …	26	12	10
Steel slot rails … … … … … …	403	12	7
Wrought-iron fishplates … … … …	10	4	6
Bolts and nuts … … … … … …	8	0	0
Intermediate yokes … … … … …	282	17	1
Joint yokes … … … … … …	102	2	10
Hatch covers .. … … … … …	58	2	10
Bent roof plates… … … … … …	583	17	2
Connecting plates … … … … …	39	5	8
Bolts and nuts for all yokes and connecting plates …	60	0	0
Labour, laying permanent way … … …	352	0	0
Insulation and suspension … … … …	200	0	0
Conductors … … … … … …	120	0	0
Royalty and various … … … … …	200	0	0
Feeders laid … … … … … …	4,800	0	0
Bonding … … … … … … …	140	0	0
Total … … … …	10,480	12	10

TABLE CI.—Showing Estimated Cost per Single Mile of Track of Conduit as Laid in Washington; Slot in Centre of Track.

	£	s.	d.
Wheel rails, slot rails and joints … … …	1,327	11	8
Conductor rails… … … .. … …	260	2	0
Bolts, nuts, washers, liners, tie-rods, &c. … …	162	11	3
Yokes, manhole frames, covers, and all cast iron …	1,040	7	10
Insulators … … … … … …	54	3	9
Malleable iron clips … … … … …	54	3	9
Bonds finished (single bonding) … … …	128	15	6
Excavation … … … … … …	487	13	8
First-class concrete for tube … … … …	1,040	7	10
Second-class concrete for paving base… … …	628	11	5
Track laying, hauling, and temporary track … …	503	18	10
Asphalte paving, in, one halfway between, and 2 ft. outside of tracks … … … … … …	1,538	18	4
Feeders … … … … … … …	4,169	8	9
Total … … … …	11,396	14	7

conductors, much more trouble is found in setting it right, the delay caused is greater, and the cost of repairs much heavier.

Leakage on conduit lines is much greater and more difficult to prevent, and insulation troubles are very much more likely to arise. The conductors being comparatively close to the roadway are much more easily damaged; and inspection being difficult, small troubles are not detected until they have developed and caused serious breakdowns.

In the design of a conduit three special points must be borne in mind:

1. The conduit must be mechanically very strong, so as to maintain an equal width of slot at all times, and under all conditions.

2. All parts of the conduit must be easily accessible, and insulators and conductors must be able to be inspected and renewed without taking up the roadway. The insulation must be of the very best.

3. The conduit should be designed to make the necessary excavation as shallow as possible. In doing this, however, care must be taken to allow the most ample drainage facilities, and manholes should be provided at frequent intervals to allow of cleaning the conduits.

According to Mr. Connett, of Washington, where double conductors are used, it is always found that the insulation resistance of the negative conductor is far smaller than that of the positive, as shown in Table CII. of tests made by him on various sections of the Metropolitan Railway Company of Washington. It was found that if the leads were reversed the same phenomenon maintained.

TABLE CII.—Showing Insulation Resistance of Conductors in Conduit Line at Washington.

Condition of Weather During Test.	Number of Circuit Tested.	Insulation Resistance in Ohms of Positive Conductor.	Insulation Resistance in Ohms of Negative Conductor.
Hard rain	1	8,300	400
"	2	8,000	480
"	3	5,200	330
Fairly dry day	1	19,500	770
" "	2	18,100	670
" "	3	10,900	770
Very dry and cold	1	36,800	1,250
" "	2	29,100	830
" "	3	27,600	910

TABLE CIII.—GIVING CAR AND EQUIPMENT REPAIRS IN PENCE PER CAR-MILE ON CONDUIT LINE AT WASHINGTON.

Miscellaneous labour	.3470
Brakes and brake shoes	.2290
Controllers	.1497
Miscellaneous repairs	.5219
Plough repairs	.6550
Wheels and axles	.1819
Tenders	.1695
Miscellaneous car repairs	.5357
Car Wiring	.2220
Tools, repairs and renewals	.0610
Armature repairs	.2971
Field repairs	.0558
Journal brasses and bearings	.2271
Miscellaneous armature repairs	.2729
Snow sweeper's and sand repairs	.0646
Painting and varnishing	.5415
Miscellaneous	.2963
Total	4.8280

General Results.

Car mileage	95.696
Total B.T.U. hours	113.355
„ „ per car-mile	1.185
Coal per B.T.U.	3.9 lb.
„ car-mile	4 6 „

TABLE CIV.—GIVING EXPENSES OF POWER STATION OF ELECTRIC CONDUIT LINE IN PENCE PER MOTOR CAR-MILE ON CONDUIT LINE AT WASHINGTON.

Engineers	.9589
Firemen	.6348
Other labour	.7701
Tools, repairs and renewals	.2374
Oil and waste	.3260
Fuel	2.8056
Engine repairs	.3031
Dynamo repairs	.0083
Boiler repairs	.0031
Switchboard and wiring	.1006
Condenser	.0015
Pumps	.0087
Miscellaneous	.0015
Total	6.1697

Each of the circuits tested was approximately two miles in length, that is to say, each conductor was approximately of that length, and was supported by 1,500 insulators.

The cost of working a conduit line does not differ much from that of working a trolley line, although probably in the long run the cost of repairs to conduit, conductors, and ploughs would show itself to be heavier than in the case of the trolley. Tables CIII. and CIV. are the results obtained from nearly a year's working of the Washington line.

The amount of power required to propel cars on either system is practically the same. Table CV. is interesting in this connection, as showing the results obtained at Washington.

TABLE CV.—Data of Power and Coal Consumption on the Washington Conduit Line.

Months.	Motor Car Miles.	Pounds of Coal per B. T. Unit.	Coal per Car Mile.	Unit per Car-Mile.
October	121,929	4.31	3.38	0.785
November	114,323	4.20	3.34	0.794
December	127,070	4.04	3.01	0.745

One great advantage a conduit possesses, viz., that while a double trolley wire system is most undesirable, and the rails must be used for the return circuit, this is not true with a conduit system, and, therefore, all possible trouble from electrolysis is averted.

With the present perfected methods of bonding this last consideration is of no great importance.

CHAPTER XXVIII.

SURFACE CONTACT SYSTEMS.

OF such systems the easiest would seem to be to use the two rails as positive and negative conductors, or else to lay a third rail and use the traffic rails for the return circuit.

In the very earliest installations this was done, as, for instance, on the Lichterfelde line close to Berlin, which was constructed by Messrs. Siemens and Halske in 1881. But in order to adopt such a system the voltage used must necessarily be very low, as otherwise people and animals may easily receive shocks. With only 100 volts horses have been thrown and badly hurt. Quite recently Edison proposed a very low voltage system, using the rails as conductors. Supposing, say, 20 volts were used, it will be seen that the average current required per car would be from 625 to 700 amperes, and the feeders required would be so heavy as practically to render such a system impossible. The danger from short circuits would be enormous. The leakage in such a system would be very great, and in very wet weather the line would be practically short-circuited. For this reason inventors have been hard at work for many years endeavouring to design a surface contact system in which only that part of the track under the car would be alive. Up to the present, however, no system has stood the test of working in dirty and crowded streets. It would serve no good purpose to describe all proposed systems, and those only will be mentioned which have been practically tried.

One of the first, and which at the time attracted a great deal ot attention, is known as the Lineff system. A short experimental line was laid in London, and seemed to promise well. It was described and favourably reported on by Mr. Gisbert Kapp, but there the matter ended. It embodies an idea on which many similar systems have been worked out.

The working or contact conductor is composed of a number of short sections of iron T-rails (the top of which is about level with the street surface) supported between the track rails on an insulating trough containing throughout its entire length a continuous composite band of copper

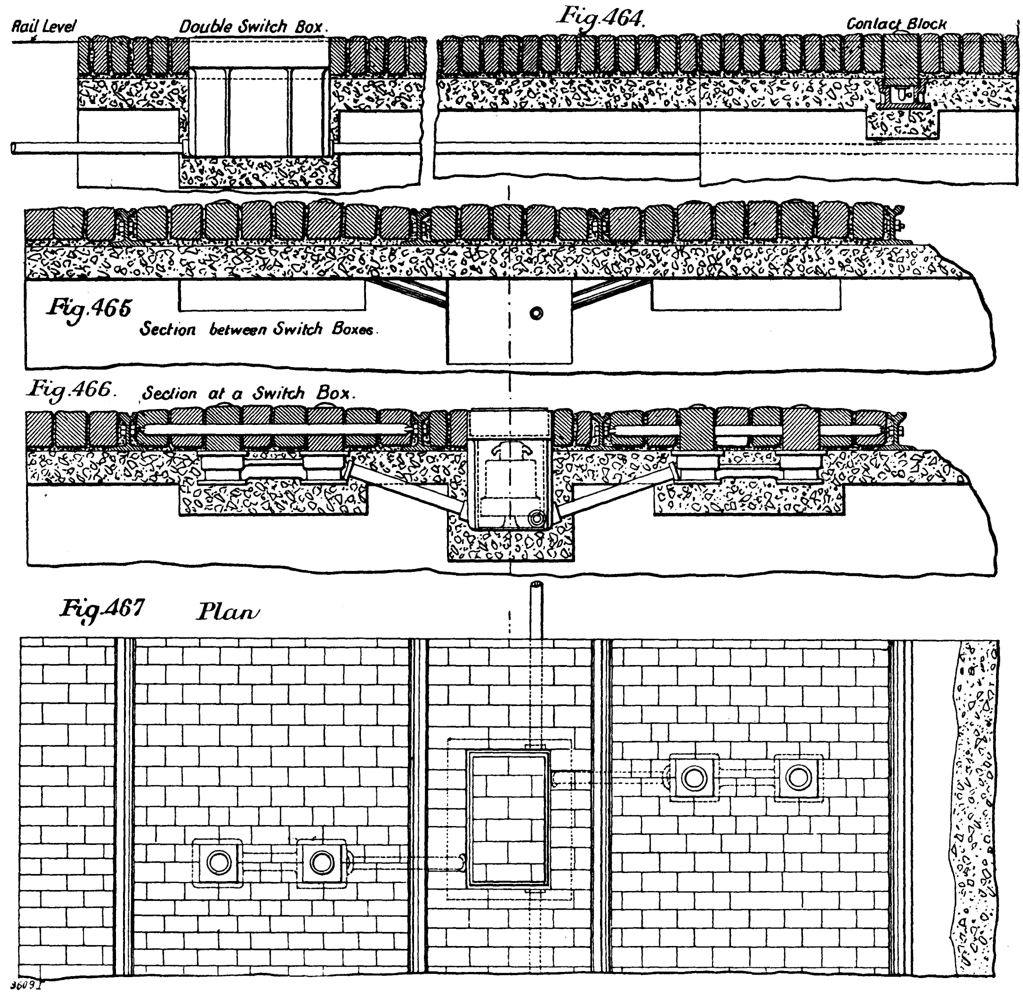
and iron, which is connected with the current generator, and is loosely supported on insulators beneath the bottom of the T contact rail. Beneath the car a large magnet is longitudinally hung, being of sufficient length to permit the iron rollers forming the poles to remain in contact with two of the contact sections. As the car proceeds, the magnet, which is energised by the same current supplying the motors, causes that part of the strip or band beneath the magnet to be drawn up against the sections in contact with the rollers of the magnet, which also collect the current from the energising contact section. As the magnet comes in contact with the next section the band drops from the previously connected section, but another portion is raised into connection with the new section, and in this way the raised portion of the band is kept moving along with the magnet under the car, connecting and disconnecting each section of contact rail. A small battery is carried, to be used in energising the magnet in starting or when the contact is lost.

Many other systems have been devised in which a flexible magnetic band or cable acts as the switching medium.

In other systems that have been devised, the switching is accomplished by means of numerous small plungers located beneath the sectional contacts and caused to operate when under the influence of the car magnet. Mr. Schuckert designed a similar system, and laid down a trial line at the Frankfort Electrical Exhibition in 1891. It was not a success, and the line was eventually run by overhead conductors. In this system iron filings were used as a switching medium. These were placed in a conical receptacle beneath the contacts, and drawn up under the action of the magnet to the more confined portion of the receptacle, thereby connecting the terminals of the main and working conductors. Section rails and continuous-attracted contact slips have now been abandoned, and in their place a series of iron knobs has been adopted. Many such systems have come out within the last few years, and one which has been experimented with on the largest scale is that known as the Westinghouse inclosed conduit, and of this a very fine working model has been exhibited in London.

It was first applied to tramway work in Washington in August 1894, and was experimentally operated until November of the same year, when regular service was begun in connection with an overhead trolley line, of which the inclosed conduit section is a spur or branch, seven-eighths of a mile in length. Since then one car has been making a 10-minute service

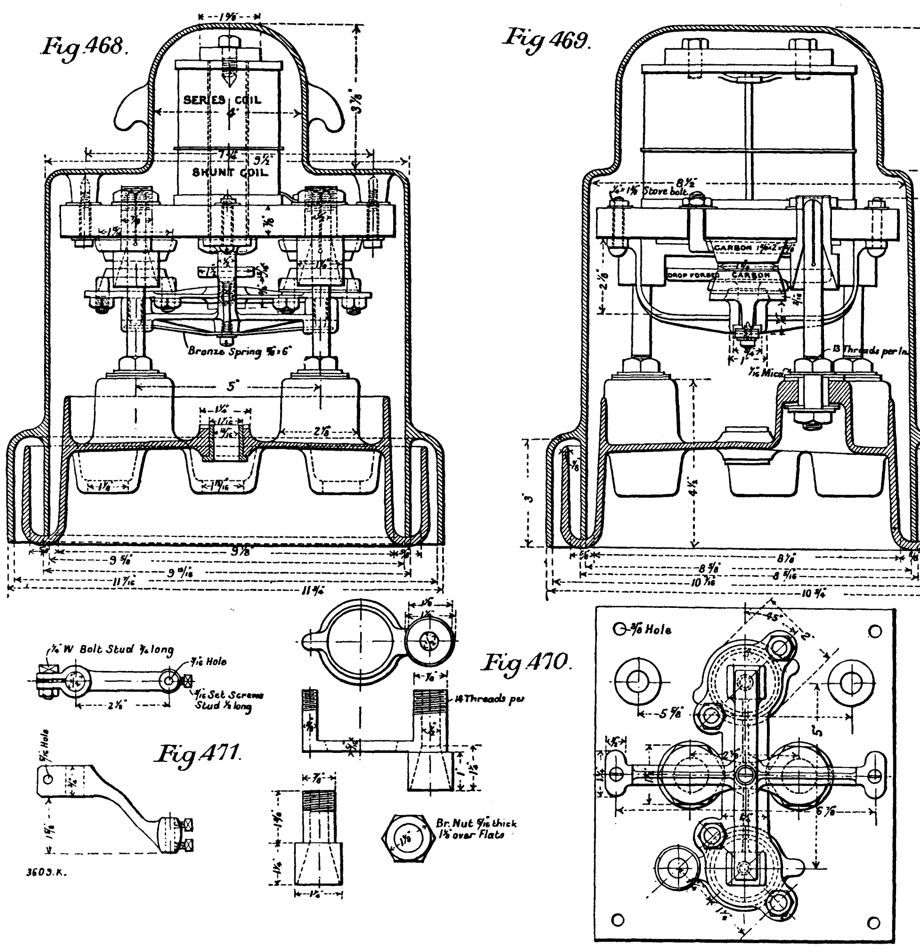
from each end of the route, or 10 return trips each hour for 12 hours a day, and 40,000 miles were run during 1895. For some of the distance the roadway is macadamised, and for a part paved. The 500-volt current ordinarily used on overhead lines is employed, and the power required to propel the car is practically the same as in overhead service.



Westinghouse Closed Conduit System.

An installation is also working at Pittsburg, Pennsylvania, in the shops and grounds of the Westinghouse Company. Here the whole of the tracks laid through workshops, fitting and erecting shops and yards, for shunting heavy railway trucks, amounting to about three miles of line, have been equipped on this system.

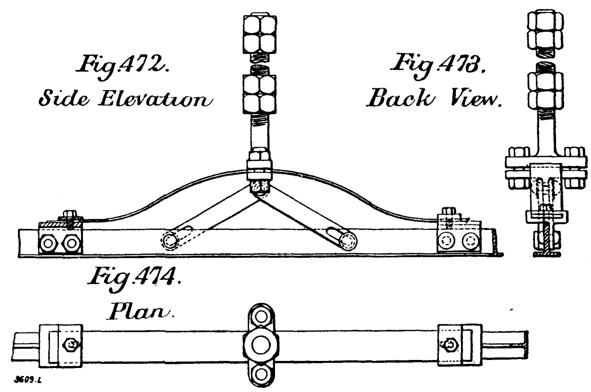
As will be seen from the illustrations (Figs. 464 to 467), the electric conductors, insulated and laid through conduits or pipes, are placed between or outside the tracks, and at intervals of about 13 ft. pass through boxes, buried at the side of the roadway or between the tracks, containing electro-magnetic switches, details of which are given in Figs. 468 to 471, from which insulated wires lead to two metal discs or knobs between the rails of



WESTINGHOUSE CLOSED CONDUIT; SWITCHBOX DETAILS.

each track. Each point is about 4 in. in diameter, and its convex surface projects not more than $\frac{1}{2}$ in. above the surface of the street. The points are corrugated to decrease the danger of the horses slipping upon them. The pairs of points are placed somewhat closer together than the length of the car, so that the collecting bars, about the length of the car, and suspended from the car truck, may always make connection with one set of

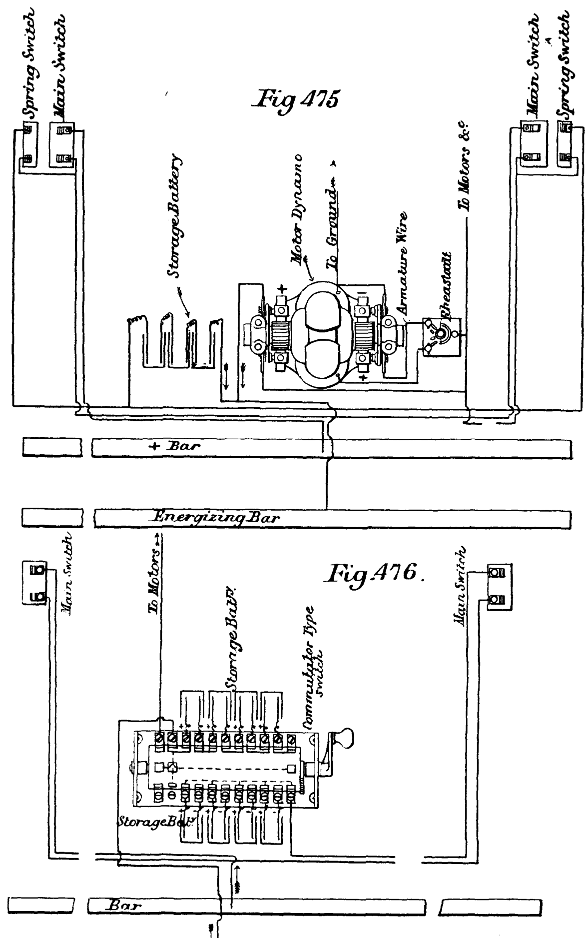
points, from which current is transmitted through the collecting bars (Figs. 472 to 474) to the car motors. A 2 in. by 2 in. by $\frac{1}{4}$ in. T-iron is used for this purpose. Except when the bar is touching the contact blocks, these are entirely disconnected from the wires conveying the electricity from the power-house, and it is stated to be impossible for either passengers or horses to receive shocks. It is only at the moment of contact with the bar, when the collector is immediately over the points, that they become alive. This is effected by means of small accumulators carried in the car, and by the electro-magnetic switch between the tracks. The poles of the battery in the car are attached to the collecting bars (Figs. 475 and 476) under the truck, and when the bars—which have a spring suspension and always press upon the points when the car is over them—touch the points,



WESTINGHOUSE CLOSED CONDUIT; DETAILS OF COLLECTING BAR.

a current is discharged from one of the bars down the metal stud and into the switch-box (Figs. 468 to 471). Here the current passes through the shunt winding of an electro-magnet that instantly attracts its armature which is connected to the main wires carrying the current from the power-house, which immediately passes through the series winding of the magnet and reappears in the second stud, whence it is collected by the second bar and passes on to the motor. The return circuit is completed through the car wheels and rails, which are bonded in the usual way. While the car is passing over the points, current continues to pass from the points to the collecting bar, but the moment the bar leaves the point the current from the battery is cut off, the armature in the switch-box drops back, and the point becomes dead. Before the collecting bars break contact with any pair of points they have come into connection with the next point, so that a continuous supply of current is provided for.

The switches are mounted in cast-iron boxes shaped somewhat like a diving bell. The base has a circular groove, which is filled with heavy oil, and the mouth of the bell has a similar groove, so that a complete oil seal is secured which prevents the entrance of any dirt or moisture. The wires enter the switch-box from the bottom, and the arrangements are such



WESTINGHOUSE CLOSED CONDUIT; DIAGRAM OF CAR CONNECTIONS.

that by merely placing the bell-shaped cover in position, all necessary contacts are made, and if any switch needs repair, the bell can be lifted oft and a new one put in place in a comparatively short time.

The construction is more costly than in the overhead system, but it is claimed to be less than the cost of an open conduit system.

The dangers of such a system are the possibility of one of the magnets going wrong and maintaining the contact knob alive after the car has passed, as well as the leakage which would probably take place in wet weather between the knobs and the rails. Where greasy mud is abundant, trouble may be anticipated from bad contacts, and there is always the possibility that the light voltage used to work the electro-magnets and contact knobs would not be sufficient to cause a current through the magnets.

That this is a very real possible trouble may be gathered from the fact that even on 500-volt trolley lines it not unfrequently happens that the lights in the car go out when passing over a very dirty piece of track, and this in a case where only one of the contacts, the rails, is bad. It is natural to anticipate greater troubles with two bad contacts and a very low voltage. A different system has been developed in France by Messrs. Claret and Vuilleumier. The idea is most ingenious, but the system is complicated.

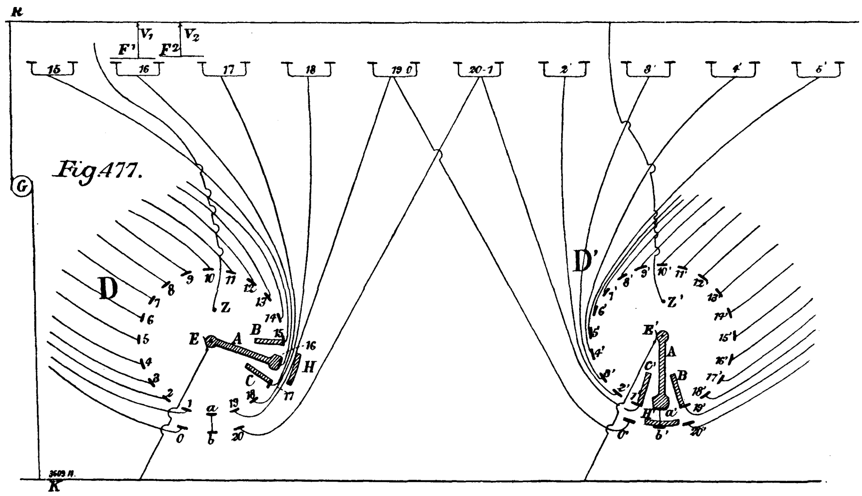
The first line was laid at Lyons and opened for traffic in May, 1894. Its length was two miles, partly double and partly single track; 12 motor cars were run.

The method of distribution adopted was somewhat similar to the Westinghouse system already described. The rails serve as return conductors, and insulated sections of rail laid between the track or cast-iron knobs are temporarily put in connection with the line when the car is passing, and cut out as soon as it has passed, the current being collected by means of a scraping contact, as in the Westinghouse system. Instead, however, of each contact having a device for connecting it to the line when required, a series of contacts are connected to "distributors," which are located in manholes at intervals along the line, not necessarily in close proximity of the track. One of the poles of the dynamo G, Fig. 477, is connected to the rails, the other to an insulated cable K, which is connected every 100 yards to distributors, two of which are indicated, D and D^1. Each distributor has 20 contact pieces forming a circle, *a*, 1, 2 to 18, 19, besides three contacts O, *b*, and 20. Cast-iron contact blocks are placed between the rails about every 8 ft. and connected in pairs, 15, 16, 17, &c. The contacts O and 1 to 19, as well as the contact 20 of each distributor, are connected by insulated wires to the contact blocks in the street, 1 to 20. The contacts 19 and 20 of one distributor correspond to contacts O and 1 of the next distributor; besides this, contacts *a* and *b* are connected. Four

contact blocks A, B, C, H, which are mechanically rigidly connected but electrically insulated, can rotate round the centre E of the distributor.

A is connected by a brush contact permanently to the cable K, and its width is such that it is always touching one of the contacts; B and C rotate with H, but are not so wide. The point Z of each distributor is permanently connected to the rail return circuit. By an electrical device, when a current circulates between C and Z, the system of movable contact pieces moves forward, one contact in the direction of the hands of a clock, and a current between B and Z causes the contact pieces to move back one notch.

A car, shown in two positions, and represented in the diagram by V_1



CLARET VUILLEUMIER CLOSED CONDUIT.

and V_2, carries a sliding contact bar F_1, F_2 of such a length as always to be connected to at least one contact block in the road. When the car is as shown V_1 F_1, the moving contact piece A is connected to contact 16 of the distributor, and there is a closed circuit through the car motor G K E A, the distributor contact 16, the contact block between the rails 16 and F_1 V_1 R, and back to G. The car moves forward, and as soon as F_1 becomes F_2, and touches the two road contacts 16 and 17 simultaneously. This causes a branch current connecting C and Z, which, as already stated, causes the whole sliding contact system to move forward one notch, and A to come in contact with 17, and this cuts the current off from the rail contact 16, which becomes dead. If the car is moving in the contrary direction, the same result is obtained by means of the moving contact B of the distributor.

When the sliding contact bar of the car comes in contact with the rail contact blocks 19 and O^1, an electric circuit is formed through G K E A 18 distributor contact, 18 rail contact, the car sliding contact 19 and O^1, rail contacts and distributor contact O^1, but there is no current supplied from the distributor D^1, as sliding contact A^1 is touching a^1; the sliding contact A passes from 18 to 19, and D still supplies the current. When A comes in contact with 19 the sliding contact H connects 20 b and a, and sliding contact C is on a. When the car sliding contact F is on the rail contacts 20 and 1^1 there is a double current, one passing through 20, H, b, a, C, and Z, and the other passing through 1^1, C^1, and Z^1. These currents cause the moving contacts of both distributors to advance one notch, thus bringing D back to the first position ready to operate when the next car comes along, and causing the current to be supplied to the car by the distributor D^1. If the car is moving in the reverse direction, the same thing will be effected by the contact B of the distributor.

We will now describe the electric mechanism by which the sliding contacts of the distributor are moved backwards or forwards (see Fig. 478). The letters and numbers of this figure represent the same working parts as in the preceding diagram. As already stated, the sliding contact A of the distributor is permanently connected to one pole of the generator G, and the sliding contacts B and C of the distributor are connected to four stationary contacts M_1, N_1, M_2, and N_2, as shown in the diagram, Fig. 477.

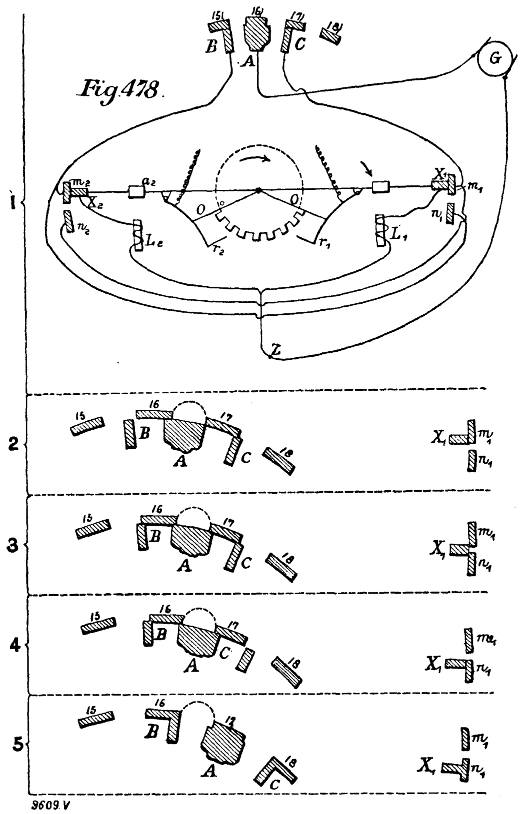
On the axis of the distributor a gear wheel having 26 teeth can rotate, and this is mechanically connected to the sliding contacts A, B, and C. A lever is pivoted on the centre of the distributor, having at each end two contact pieces, X_1 and X_2, which are insulated from each other, and this lever carries two soft iron armatures a_1 and a_2 which can be attracted by the two electro-magnets L_1 or L_2.

Besides this, two independent ratchets are pivoted on the centre, and are normally not in contact with the ratchet wheel shown. The point Z, one end of which is connected to the return circuit, is connected to the two electro-magnets L_1 and L_2, and through these with the contacts X_1 and X_2. When the system is not working X_1 is connected to M_1, and X_2 to M_2. According as the lever is attracted by L_1 or L_2, the contact X_1 is either connected to M_1 and N_1 simultaneously, or to N_1 alone, or in contact with neither, and the same holds good for X_2.

If the contacts A, B, and C are connected as shown in Fig. 478, and the sliding contact of the car is only touching the two road contacts marked

16, the contacts 15 and 17 of the distributor are insulated, and no current goes through the magnets L_1 and L_2. When the car advances, 16 is connected to 17, and a current passes through the magnet L_1, which attracts the armature a, and the lever forces down the ratchet r_1, and this causes the ratchet wheel, and therefore the contacts A, B, and C, to rotate, and the various contact pieces will successively occupy the positions shown in numbers 1, 2, 3, 4, and 5 of Fig. 478, and during the whole of this

Fig. 478.



Claret Vuilleumier Closed Conduit; Details of Distributor.

movement a current from the generator G will pass through L_1 either through G, A, 16, 17, C, M_1, X_1, L_1, Z, and back to G, or else through G, A, 16, B, N_1, X_1, L_1, Z, and back to G. But before the contact B comes in contact with the contact 16 of the distributor, the contact X_2 will no longer be in contact with M_2 and N_2. When the sliding contact of the car has left the rail contact 16, and is only connected to 17, a current no longer goes through the magnet L_1, and the ratchet r_1 is brought back to its original position, the wheel, however, having advanced one tooth. When

the car contact touches the rail contacts 17 and 18 simultaneously, the operation just described recommences. If the car is going in the opposite direction, the same thing happens, the only difference being that it is the magnet L_2 which is acted upon instead of L_1.

By making proper connections between the distributors, there is no difficulty in arranging points and crossings, but having explained the principle of the system, it is unnecessary to go into details.

The most important part of this system is the distributor. It is circular in shape, and its outside diameter is about 20 in., its height being slightly less.

M. Claret has just completed a line in Paris which is an improvement on that of Lyons. This line starts at the Place de la République, goes through the Avenue de la République, the Avenue Gambetta to Romainville, one of the suburbs of Paris. The concession for this trial line in Paris has only been granted for two years, and should the system then prove a success it will be prolonged. The first part of the line was opened last June, and when completed it will comprise some $4\frac{1}{2}$ miles of double track.

This system possesses many apparent advantages, but contâins in itself many parts which may easily lead to disaster. As far as the street goes, the same dangers are to be apprehended as in the case of the Westinghouse system and all other surface contact methods hitherto proposed. This system has an advantage in the case of railways, that it absolutely prevents cars following each other except at a given interval, as otherwise the distributors would not have worked round, and consequently no current would be supplied to the rail contacts. But this very point is a most serious objection in the case of a tramway.

Should a motor-man run by impetus, and reduce the fixed distance between the cars, no more current would be available for the car, and before it could be furnished the corresponding distributors would have to be moved round to their proper places by hand.

Another probable source of trouble is the enormous number of insulated wires which will have to be laid and properly connected, and should one of these give out it will not only be most difficult to trace, but until it is repaired traffic will be stopped. Other causes of danger are the numerous rotating parts and contacts of the distributors, which are liable to burn or become clogged, with resultant interruption of service. While we admire the ingenuity of the inventors and the admirable way in which

details have been worked out, we cannot but see that the possible causes of failure are very numerous. A prolonged practical test in crowded and dirty streets with a heavy service is needed to demonstrate its virtues and defects.

TABLE CVI.—APPROXIMATE COST OF ONE MILE OF SINGLE TRACK ON THE CLARET SYSTEM.

	£
Steel rails, fishplates, bolts, and nuts	862
Excavation and laying track	356
Cement concrete, paving, and grouting...	2,280
Main feeder cable, laying same and other necessary wires laid	1,500
Rail contact devices, insulation for same and fixing	500
Distributors, manholes, and fixing	600
Various expenses...	300
Total	6,398

Whilst it is certain that such a system could be put in more cheaply than conduits as at present constructed, there is no doubt but that it would be considerably more expensive than a well-established trolley line, besides being far more complicated and liable to get out of order.

The experimental road now running at Paris will be watched with the greatest interest. Till the line has been running well over a year, however, no definite conclusion can be reached.

CHAPTER XXIX.

STORAGE BATTERIES AS APPLIED TO TRACTION PURPOSES.

IT is not proposed to discuss the theory of electrical storage, or to go into detailed descriptions of various types of accumulators.

Accumulators can be used in connection with traction in two essentially different ways:

1. The accumulators are carried by the car and furnish the energy for its propulsion.

2. The accumulators are set up in the central or sub-stations, and, jointly with the main generating plant, furnish power to the motors through the line conductors.

The former is undeniably the ideal method of electric traction, but unfortunately has proved financially unsuccessful, except where used under exceptionally favourable conditions.

In May, 1881, Raffard equipped a car with accumulators. It held 50 passengers, and used Planté cells, each cell weighing $17\frac{1}{2}$ lb., and 16 such cells being carried in one wooden box. The discharge rate was 40 amperes at 120 volts pressure.

In 1883 an accumulator car was put in service and tested at Kew. This car was equipped with a Siemens dynamo running as motor, and carried 50 cells weighing about 2 tons. This car ran for some time at the rate of 6 miles an hour.

In 1885, Anthony Reckenzaun constructed an accumulator car which ran for some time on the lines of the South London Tramway Company. This car carried 60 accumulators, weighing $2\frac{1}{2}$ tons. Although the weight of accumulators was very great, they had to be very much overworked in order to run the car at its normal speed of 6 miles per hour, and their deterioration was very rapid.

At the end of 1885 a Reckenzaun car was run on the lines of the Berlin Tramways Company.

Later on, experiments were made with accumulator cars in Australia, and in 1887 a regular service of accumulator cars was run for some time in

Philadelphia by Reckenzaun. Since that time many further trials have been made in Europe and America.

Two principal causes have so far prevented the successful use of accumulator cars: their great weight and rapid deterioration of plant. Owing to these causes, the manufacturers of storage batteries only have seriously taken up accumulator traction; and although they have been working on this problem since 1880, little reliable information has ever been made public, and the number of lines now solely running by accumulator cars is very small.

There are, practically speaking, only two which are worth describing. One is now running in Paris, and the other in New York.

Table CVII. gives the working cost per car-mile of the accumulator cars which for several years have been running at Birmingham. The whole Birmingham system will probably soon be transformed into a trolley system.

TABLE CVII.—GIVING COST OF RUNNING PER CAR-MILE OF BIRMINGHAM ACCUMULATOR CARS FOR 1893.

	d.
Wages	3.37
Fuel	1.76
Stores	0.68
Water and gas	0.12
Sundries	0.17
Repairs and maintenance	5.49
Total cost per car-mile	11.59

Number of car-miles run, 140,993.

There is, however, one particular case in which accumulators seem to promise a fair success, and that is when for comparatively short distances, local authorities refuse to sanction the trolley wire. In such cases a battery of accumulators is put on the car, and while running along that portion of the route which is equipped with conductors the motors are run from the trolley wire, the accumulators being in parallel on the motor circuit and charged from the trolley wire. When the unequipped section is reached, the trolley pole is pulled down and the accumulators run the car. Such a system has been running at Hanover and Dresden, but unfortunately for a comparatively short time, and no figures are obtainable as

to depreciation and maintenance. The weight of the accumulators, which cannot under present conditions be less than 2 tons, is naturally greatly against their use, especially if there are many grades.

Where cells are put in cars, great care must be taken to prevent acid oozing out and ruining the passengers' clothing. If the cells are entirely boxed in, ventilation must be provided, and the air space connected by means of a chimney to the roof of the car.

The latest practice is to carry the accumulators not in the car body, but on the motor truck. This system has been adopted at New York, and is described hereinafter. Tables CVIII., CIX., CX., and CXI. give the various weights, charge and discharge rates of various types of accumulators for traction purposes.

TABLE CVIII.—GIVING DATA OF E.P.S. ACCUMULATORS OF HIGH DISCHARGE TO PUT ON CARS FOR TRACTION PURPOSES.

Description of Cell.	Number of Plates.	Capacity in Ampere-Hours.	Working Rates.		Dimensions in Inches.			Weight.		Weight of Dilute Acid.
			Discharge in Amperes.	Charge in Amperes.	Length.	Width.	Height.	Of Plate.	Cell Complete.	
									lb.	lb.
Wood, with lid	11	66	1.20	16.20	$6\frac{3}{4}$	$8\frac{3}{8}$	$13\frac{3}{8}$	..	38	10
Ebonite, no lid	11	66	1.20	16.20	6	$7\frac{3}{4}$	$12\frac{3}{4}$	..	30	10
Wood, with lid	15	95	1.30	24.28	$9\frac{1}{4}$	$8\frac{3}{4}$	14	..	53	14
Ebonite, no lid	15	95	1.30	24.28	8	$7\frac{3}{4}$	$12\frac{3}{4}$	..	42	14
Wood, with lid	19	120	1.40	30.35	$11\frac{1}{4}$	$8\frac{1}{2}$	$13\frac{3}{8}$	..	66	18
Ebonite, no lid	19	120	1.40	30.35	$10\frac{1}{8}$	$7\frac{3}{4}$	$12\frac{3}{4}$	..	54	18
Wood, with lid	23	145	1.50	38.42	$13\frac{1}{2}$	$8\frac{3}{4}$	$13\frac{3}{8}$	..	80	22
Ebonite, no lid	23	145	1.50	38 42	$12\frac{1}{4}$	$7\frac{3}{4}$	$12\frac{3}{4}$	..	66	22

TABLE CIX.—GIVING DATA OF TUDOR ACCUMULATORS FOR TRACTION PURPOSES.

Description of Cell.	Number of Plates.	Capacity in Ampere-Hours.	Working Rates.		Dimensions in Inches.			Weight.		Quantity of Diluted Acid in Gallons.
			Discharge.	Charge.	Length.	Width.	Height.	Of Plates.	Cell Complete.	
								lb.	lb.	
In Ebonite boxes	3	20 18 15	10 18 30	30	$2\frac{1}{2}$	8	13	$12\frac{1}{2}$	21	0.45
,, ,, ...	5	40 36 30	20 36 60	60	$3\frac{3}{4}$	8	13	$22\frac{1}{2}$	36	0.85
,, ,, ...	7	60 54 45	30 54 90	90	$5\frac{1}{4}$	8	13	$32\frac{1}{2}$	51	1.25
,, ,, ...	9	80 72 60	40 72 120	120	$6\frac{3}{4}$	8	13	42	65	1.60
,, ,, ...	11	100 90 75	50 90 150	150	8	8	13	52	80	2.00

TABLE CX.—Giving Data of Chloride E.S.S. Accumulators for Traction Purposes.

Description of Cell.	Number of Plates.	Capacity in Ampere-Hours.	Working Rates.		Dimensions in Inches.			Weight of Cell Complete in Pounds.
			Discharge in Amperes.	Charge in Amperes.	Length.	Width.	Height.	
Ebonite boxes	3	27	27	9 to 14	3	8 to 9½	11½ to 13	35
,, ,, ...	5	54	54	18 ,, 28	4	8 ,, 9½	11½ ,, 13	46
,, ,, ...	5	78	26	18 ,, 28	4	8 ,, 9½	11½ ,, 13	46
,, ,, ...	7	81	81	27 ,, 42	5¼	8 ,, 9½	11½ ,, 13	57
,, ,, ...	7	117	39	27 ,, 42	5¼	8 ,, 9½	11½ ,, 13	57
,, ,, ...	9	108	108	36 ,, 56	6½	8 ,, 9½	11½ ,, 13	68
,, ,, ...	9	156	52	36 ,, 56	6½	8 ,, 9½	11½ ,, 13	68
,, ,, ...	9	168	28	36 ,, 56	6½	8 ,, 9½	11½ ,, 13	68
,, ,, ...	11	135	135	45 ,, 70	7¾	8 ,, 9½	11½ ,, 13	79
,, ,, ...	11	195	65	45 ,, 70	7¾	8 ,, 9½	11½ ,, 13	79
,, ,, ...	11	210	35	45 ,, 70	7¾	8 ,, 9½	11½ ,, 13	79
,, ,, ...	13	162	162	54 ,, 84	9	8 ,, 9½	11½ ,, 13	90
,, ,, ...	13	234	78	54 ,, 84	9	8 ,, 9½	11½ ,, 13	90
,, ,, ...	13	252	42	54 ,, 84	9	8 ,, 9½	11½ ,, 13	90
,, ,, ...	13	270	30	54 ,, 84	9	8 ,, 9½	11½ ,, 13	90

TABLE CXI.—Giving Data of Epstein Accumulators for Traction Purposes.

Description of Cell.	Number of Plates.	Capacity in Ampere-Hours.	Working Rate.		Dimensions in Inches.			Weight of Cell with Acid.	Weight of Acid.
			Discharge.	Charge.	Length.	Width.	Height.	lb.	lb.
Ebonite boxes, with lids	3	62	5	7 to 10	8½	$1\frac{9}{16}$	12⅝	18	3½
,, ,, ,, ...	3	55	6	7 ,, 10	8½	$1\frac{9}{16}$	12⅝	18	3½
,, ,, ,, ...	3	53	8.5	7 ,, 10	8½	$1\frac{9}{16}$	12⅝	18	3½
,, ,, ,, ...	3	47	15	7 ,, 10	8½	$1\frac{9}{16}$	12⅝	18	3½
,, ,, ,, ...	5	124	10	14 ,, 20	8½	3	12⅝	33	5½
,, ,, ,, ...	5	110	12	14 ,, 20	8½	3	12⅝	33	5½
,, ,, ,, ...	5	106	17	14 ,, 20	8½	3	12⅝	33	5½
,, ,, ,, ...	5	94	30	14 ,, 20	8½	3	12⅝	33	5½
,, ,, ,, .	7	186	15	21 ,, 30	8½	$4\frac{1}{16}$	12⅝	47	10
,, ,, ,, ...	7	165	18	21 ,, 30	8½	$4\frac{1}{16}$	12⅝	47	10
,, ,, ,, ...	7	159	25	21 ,, 30	8½	$4\frac{1}{16}$	12⅝	47	10
,, ,, ,, ...	7	141	45	21 ,, 30	8½	$4\frac{1}{16}$	12⅝	47	10
,, ,, ,, ...	9	248	20	28 ,, 40	8½	5¼	12⅝	61	15
,, ,, ,, ...	9	220	24	28 ,, 40	8½	5¼	12⅝	61	15
,, ,, ,, ...	9	212	34	28 ,, 40	8½	5¼	12⅝	61	15
,, ,, ,, ...	9	188	60	28 ,, 40	8½	5¼	12⅝	61	15
,, ,, ,, ...	11	310	25	35 ,, 50	8½	6½	12⅝	75	20
,, ,, ,, ...	11	275	30	35 ,, 50	8½	6½	12⅝	75	20
,, ,, ,, ...	11	265	42	35 ,, 50	8½	6½	12⅝	75	20
,, ,, ,, ...	11	235	75	35 ,, 50	8½	6½	12⅝	75	20

Table CXII. gives the comparative data as to weights and capacities of accumulator cars as tried at Paris, Berlin and Vienna.

TABLE CXII.—Giving Comparative Data of Accumulator Cars as Experimented on in Various Towns.

Items.	Paris.	Berlin.	Vienna.
	Lead Accumulators.	Lead Accumulators.	Copper-Zinc Accumulators.
Passengers carried	50	31	32
Empty car weight in pounds	18,081	19,845	16,097
Loaded ,, ,, ...	25,799	24,630	21,036
Weight of cells in pounds	3,749	7,270	3,969
Number of cells	56	88	136
Capacity of cells in ampere hours	230	130	300
Power per car-mile required at power-house in Board of Trade units	1.120	1.072	1.280

Table CXIII., for which we are indebted to the courtesy of Mr. P. Van Vloten, a Belgian engineer of high standing, gives some interesting figures obtained on the accumulator line running at The Hague. It will be seen that the cost of handling and maintaining these accumulators is 1.08d. per car-mile, a very heavy item in operating expense.

TABLE CXIII.—Giving Data of Accumulator Line Running at the Hague (1891)—Julien Accumulators.

Length of line	$3\frac{1}{2}$ miles
Maximum gradient	1 : 50
Weight of each car loaded	14 to 16 tons
Number of cells on each car	192
Weight of accumulators	4 tons
Maximum speed of cars in miles per hour	12.5 miles
Maximum distance run by cells with one charge ...	44 „
Average distance run	35 „
Capacity of cells in ampere-hours per pound of plate	4.5
Positive plates can run without renewal for ...	9,000 to 11,300 miles
Cost of maintenance of cells per car-mile	0.85d.
„ handling cells per car-mile	0.23d.
Board of Trade units consumed per car-mile run ...	1.08
Probable maximum discharge rate	130 amperes

The Paris accumulator line belongs to the Paris Tramway Company. There are three separate lines, namely, St. Denis-Madeleine, St. Denis-Opera, and St. Denis-Neuilly. The total length of track over which the cars run is about $9\frac{3}{4}$ miles. The first line was inaugurated in the beginning of 1892, and the last started in the middle of 1893. The average car-mileage per month is 50,000 car-miles. The cars employed are double-deckers, and carry 50 passengers. They are lighted by four incandescent lights run off the battery circuit. The maximum gradient is 3.8 per cent. Two motors are fitted on each car, and drive the axles by means of double reduction gear, the ratio of the reduction being 12 to 1. The armatures run 1,350 revolutions per minute at their normal speed, and are rated at approximately $13\frac{1}{2}$ electrical horse-power each.

The accumulators used on these cars are of the Laurent-Cely type, and are placed under the seats of the cars. There are 108 cells in each car, and they are contained in ebonite boxes. Table CXIV. gives dimensions and other data of the cells employed. The 108 cells are divided up into 12 separate boxes, six being put on each side of the car under the seats. Each car can run approximately 37 miles without having to change

accumulators. The speed regulation is obtained by putting the various groups of batteries in parallel or series.

TABLE CXIV.—Giving Data of Accumulator Cars Running in Paris.

Number of cells	108
„ plates in each cell	11
Height of plate in inches	$7\frac{7}{8}$
Width „ „	$7\frac{7}{8}$
Thickness of negative plate in inches	.236
„ positive „ „	.315
Weight of plates in pounds	39.69
Capacity in ampere-hours	250
Efficiency per cent.	70
Average discharge rate in amperes	35
Maximum „ „	100-120
Life of negative plate in car-miles	93,750
„ positive „ „	8,750
Passengers carried	50
Weight of car loaded in pounds	30,870
„ cells in pounds	6,615

The number of cars running on these lines averages 17 under the usual conditions of traffic. The average coal consumption per car-mile is approximately $8\frac{1}{2}$ lb. Table CXV. gives the cost per car-mile for running in the year 1893. Table CXVI. shows the comparative cost of the various systems now running in Paris. Owing to the fact that an old car-shed was utilised, it was impossible to charge the accumulators, as ought to have been done, on benches paralleling the sides of the cars. The accumulators are taken from the cars to the charging benches by means of small trucks running on rails. In the power house there are three 125 horse-power Corliss engines, each one driving a shunt-wound machine by means of belts, and furnishing a current of 230 amperes at 260 volts. All the batteries are charged at a pressure of 260 volts.

TABLE CXV.—Giving Working Expenses of Accumulator Traction in Paris for 1893 per Car-Mile Run.

	d.
General expenses	0.204
Cost of power	2.828
Maintenance and handling of accumulators	2.537
Motor-men and assistants	1.210
Maintenance of motors and trucks	1.410
Heating, lighting, and various	0.138
Total per car-mile	8.327

Miles run, 144,718.

TABLE CXVI.—SHOWING COMPARATIVE COST OF VARIOUS SYSTEMS OF TRACTION IN PARIS IN PENCE PER CAR-MILE.

	d.
Horses	8.55
Accumulators	8.33
Hot-water locomotives	5.39
The overhead trolley system	4.62

Electric storage battery traction systems are once again being tested in New York City. Most of the companies are anxious to abandon animal and to substitute mechanical power, and the New York and Harlem Railway Company has introduced the storage-battery system in an experimental way on its Madison and Fourth Avenue line. Julien storage-battery cars were operated on this line some years ago, but were abandoned.

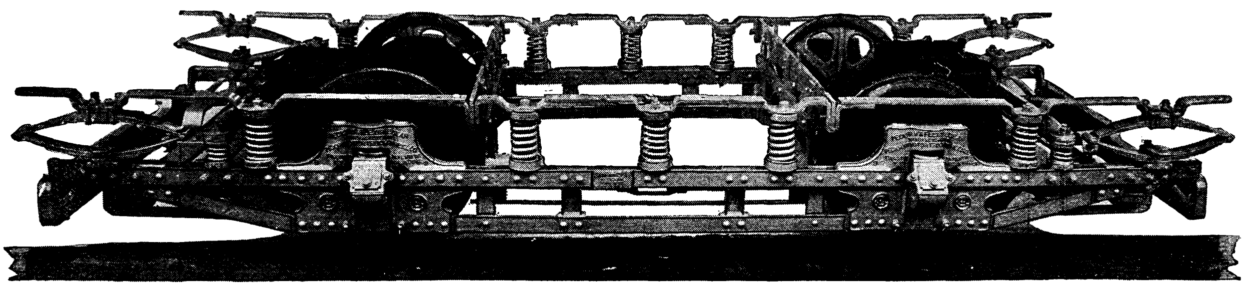


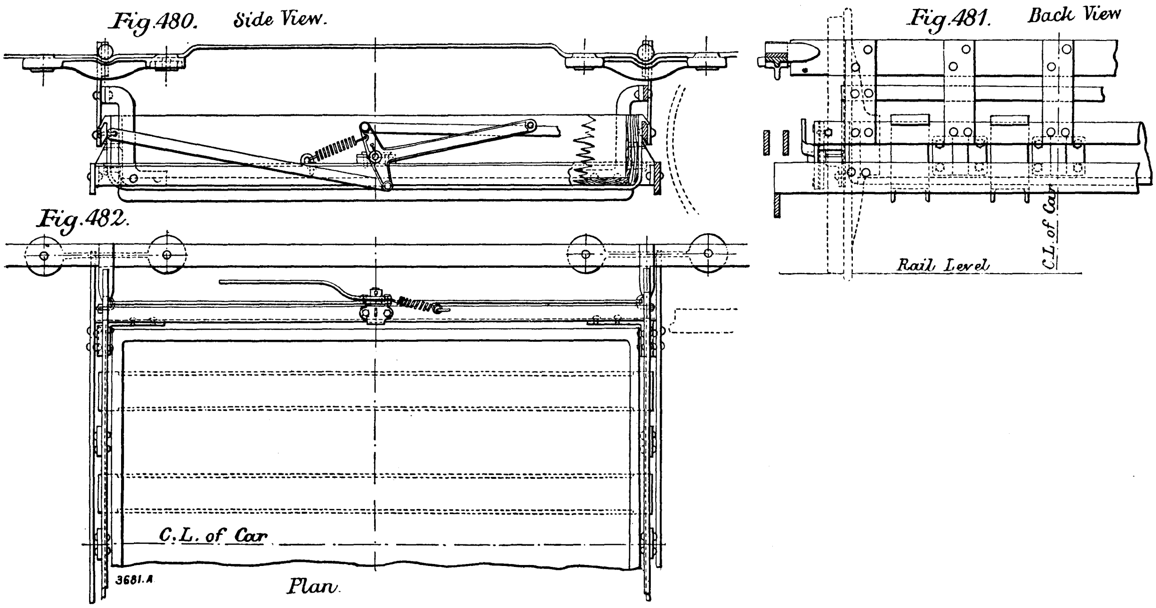
FIG. 479. "PECKHAM" ACCUMULATOR TRUCK.

The Electric Storage Battery Company of Philadelphia has equipped two cars.

The trucks were constructed especially for their work, and are of the well-known Peckham type, having a 9-ft. wheel-base. They are extra long and unusually substantial. The motors are hung from the axles on the sides opposite to those which they occupy in the ordinary equipment, as shown in Fig. 479. They are of the "G.E. 800" type, and are wound for 120 volts.

The middle of the truck is left free to receive the equipment of batteries which are carried on a platform between the axles, as shown in Figs. 480, 481, and 482. The storage cells are 60 in number, and are grouped in two batteries of 30 each. The trays carrying the batteries contain 23.83 square feet; the depth of these trays is 16 in., and the batteries extend above the top of the trays 4 in.; the trays are carried

on a framework extending across the truck and supported by a casting attached to the top frame. The controller is a modification of the General Electric "K" type, a development of which is shown in Fig. 483, and is designated as "K. S. B." The controller has six notches arranged in pairs, making connections, as shown diagrammatically in Fig. 484. Nos. 1, 3, and 5 are running notches, and when these positions are used the car gives the maximum economy. Each of the chandeliers in the cars is connected to a separate battery, so that in case of trouble with one battery the other will be available to furnish illumination. Each equipment is provided with a special box containing voltmeter contacts, so that the expert can always



"PECKHAM" PLATFORM-HOLDING ACCUMULATORS.

determine the condition of the batteries and ascertain if a sufficient charge is present to furnish power for operating the car until it returns to the charging station again.

Provision has been made for quickly furnishing cars with charged batteries, and for as speedily removing the discharged cells, and the various plans for this part of the work have been carefully worked out. It has already been stated that the 60 cells occupy a position in the centre of the truck. They are carried in a tray, to the bottom of which are attached four channel irons. To the ends of the latter are riveted wrought-iron hooks, which snap upon spring-pressed supporting bars on the truck, holding the tray securely in position, as shown in Figs. 480, 481, and 482.

The cars enter on the street level, and the cells are raised on the tray from the basement into position by means of an elevator (Figs. 485 and 486) operated by an electric motor. This elevator runs on a track laid in the bottom of the pit over which the car runs when the batteries require changing. This elevator is raised and the batteries are elevated a sufficient distance to take their weight off the hangers, when the cast-off at the side of the truck is thrown, which causes the supports for the tray to be thrown out of line with the hooks on the tray. The elevator is then lowered, and the pit car run off to a point where the batteries are recharged, and another set of batteries, which have already been recharged, are put in the car, enabling it to leave the car barn at once. This method obviates the

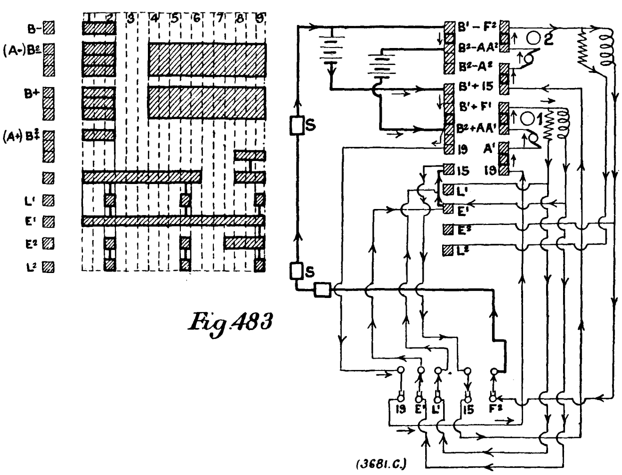


Fig 483

STORAGE BATTERY CAR CONTROLLER.

necessity of having extra cars in the barn that are being recharged while the others are out on the road.

It is necessary that the elevator should carry its tray exactly into position. As it would be out of the question to stop a heavy car within an inch or two of the required point, an automatic centring arrangement, which consists of a movable bumper on the car track capable of adjustment for a distance of about 14 in., has been devised. From the bumper a lever extends to guides at the side of the elevator pit. The movement of the lever is communicated to the guides, and they are caused to swing longitudinally into such a position that the tray slides, as it is raised, into its proper place, and the hooks hold it securely.

Upon the withdrawal of the elevator the car is ready for service. The removal of the discharged cells is as easily effected. The elevator is raised

into position, the supporting hooks are released, and the batteries then rest on a truck. The elevator carries its load to the basement, and the cells are run into the charging-room. It is stated that a change of batteries can be effected in about 30 seconds.

The terminals of the battery make automatic contact when it is hoisted into position, and the mechanism used for this purpose is ingenious. A flat brass plate on the side of the battery box impinges against two blocks, and the latter are held against cross-plates on the sides of the tray by flat springs. These blocks are absolutely insulated from any part of the mechanism which presses them against the plates. The tension of the flat

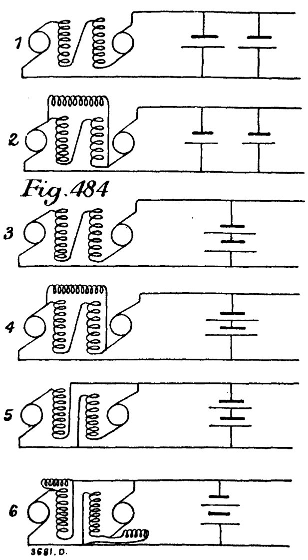
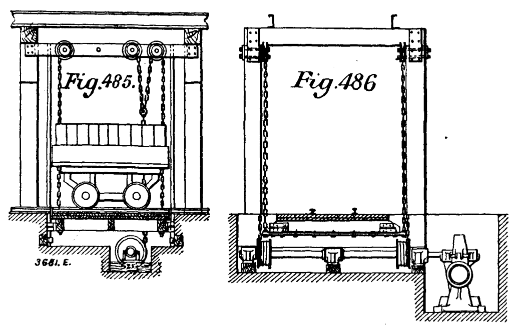


DIAGRAM SHOWING CONNECTIONS OF STORAGE BATTERY CAR.



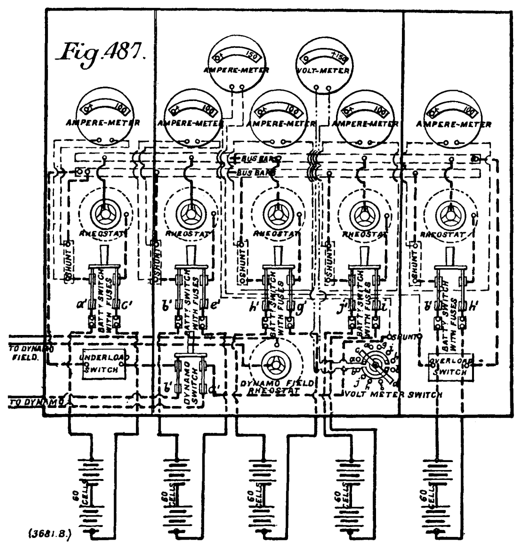
LIFTS FOR CAR CELLS.

springs is readily adjusted by two tension screws. Two of these blocks connect one terminal of the battery, an identical apparatus being used for the other connection. In the arrangement of the cars all parts of the equipment are in duplicate, so that the possibility of its becoming disabled is reduced to a minimum. All the battery connections are burned together, and the terminals are double cables.

The charging switchboard is shown in Fig. 487. The batteries are charged in series, and interposed in the circuit are two cut-outs, one of which acts if the current falls below 10 amperes, and another if the current rises above 100 amperes. This makes the charging of batteries almost automatic. The charging switchboard is of polished slate, and consists of

five panels, each containing a switch and an ammeter. The totalising ammeter and voltmeter, together with the cut-outs before mentioned, complete the present equipment. A new panel will be added to the switchboard when the plant is increased.

As stated, it is only where accumulators fitted on cars work in conjunction with a trolley line that they stand any chance of success, as is the case at Hanover and Dresden. This system was first introduced by the manager and engineer, Mr. Kruger, about the middle of 1895. Tudor cells of the Planté type are used. There 196 cells on each car, and each cell is composed of three plates, two negative and one positive. Each cell weighs



CHARGING SWITCHBOARD.

$26\frac{1}{2}$ lb., including acid, and the cars run $3\frac{3}{4}$ miles with accumulators alone. The car body and truck weigh together $4\frac{1}{2}$ tons. Each car is fitted with one Siemens and Halske 15 horse-power motor, weighing 1.2 tons. The accumulators and fittings weigh $2\frac{1}{2}$ tons, making the total weight of the empty motor car 8.2 tons. Each car carries 20 passengers inside and 16 on the platforms. The total number of motor cars running at Hanover, and fitted with accumulators, is 60, and so far they seem to have given satisfaction. It has been found, however, that three-plate cells are not very satisfactory, and this number has now been increased to five. The total number of cells—which originally was 196—has now been increased to 208 per motor car. The rheostat system of speed regulation is used, and the same controller is used for running the cars off the accumulators or

off the trolley line. When passing from the trolley line on to the section run by accumulators, the only manipulation necessary is to pull down the trolley pole, and switch the motor off rail and trolley wire on to the accumulator circuit (Fig. 488). It cannot be disguised that at best this system is a makeshift, and that the only reason of its adoption is that the local authority would not sanction the erection of the trolley wire through certain portions of the town. The adoption of accumulators when used in this way does not present all the serious disadvantages of most accumulator cars. The cells are worked under much more favourable conditions. They are very rarely entirely discharged, and owing to their practically never being handled, they can be fixed on the cars in such a permanent way as not to be liable to very great vibration. The causes which led to the

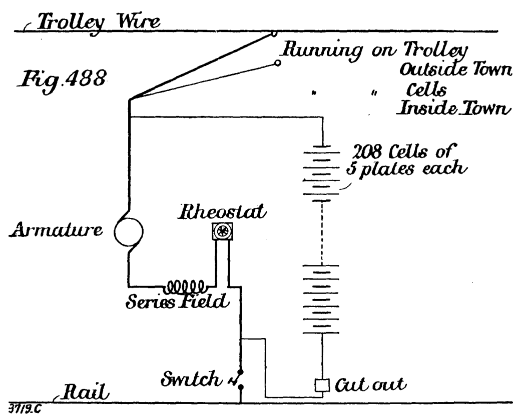


FIG. 488. DIAGRAM OF CONNECTIONS, HANOVER ACCUMULATOR CARS.

adoption of this system in preference to a conduit or a surface contact system, were purely and simply financial, and in the hope that once electric traction had proved its superiority and been adopted on the whole system, local authorities might relent and tolerate the overhead wire.

There is another manner in which accumulators can be utilised, and this is probably that which will give the greatest satisfaction, and which certainly possesses merits not to be gainsaid. This method consists in using storage batteries as an adjunct to tramway power plants, and locating them in the main power-house as equalisers of the load, or as a reserve of power at times of unusually heavy traffic, or when the engines are shut down, or else installing the batteries in sub-stations along the line. Examples of the use of accumulators in connection with electric tramway installations have already been given, as, for instance, the Hamburg and

Rome plants previously described. Attention has already been frequently called to the disadvantage under which the engines and dynamos in an electric tramway plant work, owing to the very large and rapid changes of load to which they are subjected. The variation of load compared to the rated power of engines and generators is naturally very much greater in a small plant than in a very large one, a fact proved by comparing the ampere and watt curves of a plant of several thousand horse-power to one of a few hundred.

A battery of accumulators of sufficient capacity to equalise the load in a very large electric traction plant would be so large and costly that in most cases the small advantage derived would not pay for its installation.

The difference between a lighting and traction plant is at once evident, as in the latter, although the average load may slightly vary during the day, it will, to all intents and purposes, be fairly constant for from 16 to 20 hours out of the 24; whereas in a lighting plant the reverse is the case, and the average current during a few hours in the evening is many times greater than during the whole 24 hours. Therefore, even in the largest lighting stations, accumulators may be advisable.

There are a few examples where accumulators as equalisers of load have been used very successfully, and have allowed of a very much smaller plant being installed than would otherwise have been required. The first line on which the introduction of accumulators practically took place was that belonging to the Zurich Electric Tramway Company, which was opened for traffic on March 1, 1894, and has been working satisfactorily ever since. The length of this line is approximately three miles, of which the greater part is single track. The maximum grade is 6½ per cent. for about 400 ft. The total number of motor cars now running on the line is 16. Each car seats 14 inside, and carries six on each platform, and is fitted with a 20 horse-power Oerlikon motor. The total weight of the empty motor car is about six tons. The power plant consists of two Lancashire boilers, each having 624 square feet heating surface, and working at 140 lb. steam pressure. There are two vertical compound high-speed Oerlikon engines, each about 100 brake horse-power, running at 240 revolutions per minute. Each engine belt drives a 66-kilowatt shunt-wound generator which furnishes current at a pressure of 550 volts. The battery consists of 300 Tudor cells, having a capacity of 240 ampere-hours and a maximum discharge rate of 21 amperes, which, however, for a few seconds can be doubled without injuring the cells. Each cell contains six positive and

seven negative plates. The switchboard connections necessary for such a connection have been already fully illustrated and described in pages 255 and 256, and need not be further gone into. To charge the regulating cells, a small auxiliary direct-connected 3-kilowatt set is used, furnishing current at 150 volts.

The experience gained in this installation has abundantly proved that such an auxiliary dynamo is not required, and that the main generators, by being properly connected to charging and discharging switches, can be utilised for keeping the pressure up in regulating cells. Another rather curious fact has been brought to light, viz., that it is quite as economical, if not more so, to do without the automatic regulating switch and simply leave the whole battery in parallel with the generators, instead of using the automatic device which serves to cut in and out cells three at a time so as to keep the line pressure constant when the current varies. This device has already been fully described in connection with the tramway installation at Rome (page 457). The only disadvantage of doing without this regulator is that, at night, the electric lamps in the cars burn rather unsteadily.

The advantages, in a small plant with heavy grades, of the use

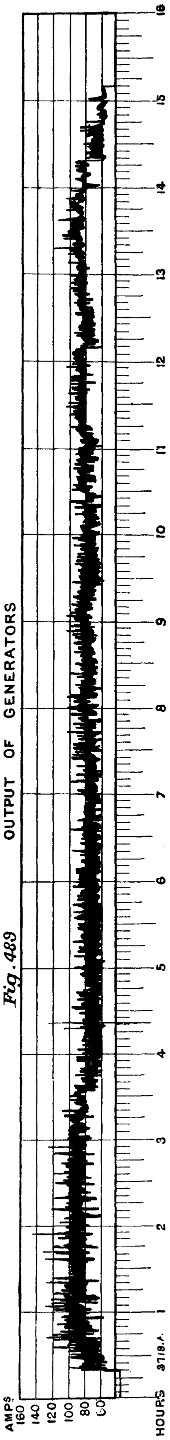


Fig. 489. OUTPUT OF GENERATORS

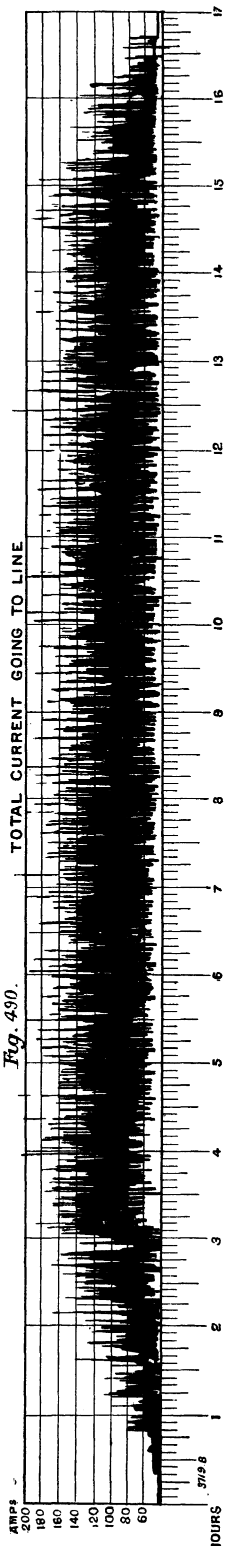


Fig. 490. TOTAL CURRENT GOING TO LINE

CURRENT DIAGRAMS OF ZURICH ELECTRIC TRAMWAYS.

of accumulators will be seen by glancing at the two ampere diagrams, Figs. 489 and 490, which give the current output as recorded by recording ammeters of the generator alone, and of the generators and accumulators combined into the overhead line. Fig. 489 shows that the current of the generators does not vary approximately more than 20 or 30 amperes, and never drops to zero, and that the maximum current does not exceed 140 amperes, the average being probably about 90. Looking now at Fig. 490, which shows the total current as furnished to the overhead line, it will be seen that the variations of current are very large and follow each other very rapidly, and that the current very frequently falls to zero, the maximum current being about 200 amperes, whereas the average would probably be more like 80. It must also be borne in mind as regards the use of accumulators in this fashion, that they are working under peculiarly favourable conditions, owing to their being constantly charged and discharged, and practically never entirely empty.

Another line, which has recently been built at Zurich, is known as the Zurich mountain line. This station is of great interest, owing to the fact that Otto gas engines are employed, and Dowson water-gas used for fuel, manufactured on the premises. By the use of accumulators it is rendered possible to employ engines such as turbines, gas engines, and single-phase alternators to drive the generators, as they will not be liable to take the strain of unexpected overloads, which will be met by the accumulators.

CHAPTER XXX.

SPECIFICATIONS.

THE specification for an electric tramway equipment should state as exactly as possible the nature of the work to be done, and set forth approximately quantities and quality of materials and workmanship, in order to afford a common and equitable basis for comparison of various tenders. The following are the general headings:

1. Conditions to which all offerers are subject.
2. Track: Permanent way and return circuit.
3. Line Work: Trolley line (including all poles, bare wires, insulators, and suspension devices, &c.). Feeders, lightning arresters, circuit breakers, &c.
4. Power House: Boilers, buildings, foundations, engines, electric generators, switchboard connections, &c., &c., and electric lighting.
5. Rolling Stock: Trucks, motor equipment, controllers, connections, lighting, trolleys, car bodies, brakes, safety appliances, &c.
6. Repair Shops and Car Sheds: Buildings, machine and hand tools, shafting, belting, &c.

General Conditions.—The following is a typical American specification:

The company reserves the right to reject any and all proposals, and to exact from the contractor a bond, satisfactory to the company, for the faithful performance of the contract, and the completion of the entire equipment within the time specified. The proposal must state the number of days after the awarding of the contract within which the entire equipment will be completed and the road ready for operation, under a forfeiture of ——— per day for each and every day elapsing between the date specified and the date of completion.

The road shall be considered complete when cars have been run over it by the contractor from end to end, without any damage to any part of the work and without resort to temporary expedients.

In case any extra work is to be performed by the contractor, he must obtain from the company's engineers written authority to perform such extra work, and this authority must state price for which the work is to be done.

All workmanship and material of every kind or character for any work to be done under these specifications, shall at all times be subject to the inspection of the company's

engineers, and both the labour and material must be first-class in every particular and satisfactory to the engineers.

If any unfaithful or imperfect work shall be discovered at any time prior to the final and complete acceptance of the whole work, the defects shall be immediately corrected by the contractor at his own expense, and to the entire satisfaction of the engineers; but the inspection of the work shall not be considered as relieving the contractor from any of his obligations to execute the work in a durable and satisfactory manner as required by the specifications.

If the contractor shall neglect to proceed immediately to the correction of any defect as required by the engineers, said engineers may employ men to effect the requisite correction at the expense of the contractor, the cost thereof to be taken by the company from any moneys due to the contractor.

Rights and Franchises.—The company agrees to procure and possess all the necessary legal rights, franchises, and rights of way, in advance of the work, and to acquire from time to time such additional rights as may be necessary as the work proceeds; also to prevent and remove any interruptions which may arise or be attempted, so as to afford the contractor the necessary facilities for carrying the work on continuously and rapidly.

The engineers of the company will furnish the contractor all the lines, levels, and centre lines; and grade stakes will be set by the engineers at suitable intervals.

The contractor shall not allow any *débris* or rubbish to accumulate, and the streets and premises must be kept clear, and the contractor must keep all work in neat condition and leave it clean and complete in every particular.

Accidents, Damages, &c.—The company shall not in any manner or to any extent during the continuance of this work be liable for any loss, injury, or damage that shall or may arise or happen to the work done, or to the material supplied, or to men employed by the contractor in or about the work. Should any person or persons or property be damaged or injured by the contractor, or by any person or persons employed by him during the performance of this work, said contractor shall alone be liable, and shall hold the company harmless from all suits, expenses, or any damages by reason thereof. The contractor shall furnish proper lights and other safeguards for avoiding accidents, and shall comply with all local ordinances and regulations as to tearing up streets and lighting the work in progress, &c.

The contractor shall furnish a competent man to start the plant and supervise its operation for ——— days. If the various portions of the road operate during this period to the satisfaction of the engineers, the road shall be accepted at the end of this period of ——— days; but if during this period the engineer shall note any defects or deficiencies in the road, a list of such defects and deficiencies will be furnished the contractors, and when these have been made good or repaired, the road will be accepted by the engineers on behalf of the company.

Track—Permanent Way.—This should set forth all earthwork, paving, weight and style of metals, and all platelayers' work under their various headings.

In making out the specifications for the material and labour under the heading "Permanent Way," a rail weighing not less than 75 lb. per yard should be specified if possible. Both in America and on the Continent the best practice calls for 90 lb. to 100 lb. rails. How the joints are to be laid

should be clearly set forth. In paved streets the rails should be butt-jointed, and sole-plates used to give the best results. No space should be left for contraction and expansion. It has been found that the paving keeps the rail at a fairly even temperature, and that the strains are within the elastic limit of the metal.

HEADINGS FOR SPECIFICATIONS OF PERMANENT WAY.

Material:
- Rails.
- Fishplates and bolts.
- Tie-bars.
- Points, crossings, and special work.
- Tests.

Roadbed:
- Excavation.
- Removal of rubbish.
- Concrete, and how laid.
- Surfacing.
- Gauge and levels.

Roadbed—(Continued):
- Laying track and special work.
- Curving rails.
- Joints.
- Watching and guarding.

Paving:
- Bedding.
- Stone setts paving.
- Asphalte paving.
- Wood paving.
- Macadam paving.

A small space may be left between the rails every 300 ft. to 500 ft. Some engineers go so far as to specify that thin sections of rails shall be put between the joints where the rails have been laid in summer and where the cold of winter has caused the rails to contract and leave spaces at joints. The life of the joints is thus substantially increased and a very much smoother track secured.

Fishplates with a double row of bolts are recommended. Fishplates should be from 28 in. to 36 in. long, with eight to 12 bolts in each. The best and strongest special work should always be specified. Dummy points should not be used, as they cause serious jolting and increase the cost of maintenance of trucks and motors.

Crossings should be of the toughest possible steel. The following is a very recent specification for a 75-lb. grooved girder rail.

The engineer shall select pieces of rail from those supplied by the contractor, and these shall be tested in the following manner: A 6-ft. length of rail shall be supported in a running position on iron supports 3 ft. apart in the clear, and a weight of 20 cwt. shall be dropped freely on the centre from a height of 20 ft. The deflection under the blow shall not exceed 4 in., or be less than 2 in., and the rail shall not show any signs of fracture. A piece of the rail shall also be turned up and tested in an approved testing machine, when it shall sustain a load of not less than 35 tons per square inch, with a reduction of fractured area of not less than 30 per cent. Rails, samples of which do not satisfy the above test, shall be rejected. The engineer shall be at liberty to select a sample for testing from each cast of steel. The

engineer shall select samples of the fishplates for testing, and these shall show an ultimate tensile strength of not less than 28 tons per square inch, and a reduction of fractured area of not less than 35 per cent.

Where, as in England, the metals are usually on a concrete bed, Portland cement should always be used with clean sharp sand and broken stone of a size which will pass through a 2-in. ring. This bed should be at least 6 in. thick (8 in. would be preferable), and the concrete should always be fresh. Cement concrete is to some extent an insulator, but to make it still more difficult for the return current to leave the rails, a layer of about 2 in. of asphalte concrete may be laid just below the rails, and their sides filled level with the paving setts with the same material.

Line Work.—Great care should be taken that only the best materials and workmanship are employed; a saving can only amount to a very small percentage of total expenditure, and anything going wrong with this portion of the work is absolutely fatal to the successful working of the line.

The following specification is in accord with the best and most recent practice in England and America:

SPECIFICATION FOR LINE WORK.

Standards.—The standards will be of five types, and will be known as "No. 1," "No. 2," "No. 3," "No. 4," and "No. 5" poles. These to be made in not more than three sections, the tubes at joints to be telescoped into each other from 15 in. to 18 in. Joints to be solid swaged and shrunk together. No liners allowed. Tubes composing poles to be put together so that their seams do not coincide. Tubes composing poles to be of best quality iron or steel, and lap-welded. The larger poles, Nos. 4 and 5, to be welded and riveted. Tensile strength of material to be at least 50,000 lb. per square inch. Factors of safety must in no case be inferior to 4, and preferably 5.

No. 1. To withstand lateral strain of 350 lb. applied at the top, with a temporary deflection not exceeding 6 in., and a strain of 700 lb. with a permanent deflection not exceeding $\frac{1}{2}$ in. Weight not to exceed 720 lb.

No. 2. To withstand lateral strain of 500 lb. (as above) with a temporary deflection not exceeding 6 in., and 1,000 lb. with a permanent deflection not exceeding $\frac{1}{2}$ in. Weight not to exceed 840 lb.

No. 3. To withstand lateral strain of 700 lb. (as above) with a temporary deflection not exceeding 6 in., and 1,200 lb. with a permanent deflection not exceeding $\frac{1}{2}$ in. Weight not to exceed 990 lb.

No. 4. To withstand lateral strain of 1,000 lb. (as above) with a temporary deflection not exceeding 6 in., and 1,700 lb. with a permanent deflection not exceeding $\frac{1}{2}$ in. Weight not to exceed 1,330 lb.

No. 5. To withstand lateral strain of 2,000 lb. with a temporary deflection not exceeding 6 in., and 2,600 lb. with a permanent deflection not exceeding $\frac{1}{2}$ in. Weight not to exceed 1,600 lb.

Weights above stated to be closely approximate, and strains specified to be absolutely fulfilled. The poles to be as nearly round as possible; $\frac{1}{8}$ in. between maximum and minimum

diameter to be deviation allowed. All to be as nearly uniform as possible, $\frac{1}{16}$ in. more or less than specified dimensions to be maximum deviation; $\frac{1}{4}$ in. to be greatest distance out of true allowed at top, 10 per cent. of each lot to be tested. Should three poles fail to meet specification, the engineer to have the right to reject all. Poles will be dropped, butt foremost, from a distance of 6 ft. on to some solid substance three times, and must show no signs of telescoping or loosening at joints. All poles to be furnished complete with cast-iron tops and bases of approved design. Bracket arms where required to be made as follows: Arms to be of 2-in. iron or steel pipe. For arms up to 12 ft., one tie-rod of $\frac{3}{4}$-in. iron to be used, and arranged so as to be able to be tightened or slackened as required. For brackets of 14 ft. and over, two 3-in. tie-rods to be supplied. Brackets to be fixed on the pole ends by iron castings bolted together, the tube to be firmly attached to castings. Cast-iron finals to bracket, fixed by pins. Brackets to be so constructed that after a strain of 1,000 lb. has been applied at their extremity (erected), no appreciable deflection can be observed. All poles and brackets to be painted with two coats of best lead and linseed oil paint, colour to be selected by company.

Erection.—Nos. 1, 2 and 3 poles to be set in holes 6 ft. 6 in. deep. First 6 in. to be filled with concrete. Pole to be dropped in and rest on flat stone or piece of wood, so as to prevent concrete rising inside. Holes to be, as far as practicable, not more than 20 in. in diameter at any point. Concrete to be fresh made, and composed of 1 part Portland cement, 2 parts clean sharp sand, and 3 parts sharp clean broken stone. Side poles to be set with a rake of from 6 in. to 18 in., according to the quality of the ground, and at such a distance from the kerb that the base is approximately 1 in from the face of the kerb. Bracket arm poles on a straight line to have a rake of 2 in. to 4 in.; on a curve, a rake forward or backward of from 6 in. to 18 in. Nos. 4 and 5 poles to be set from 6 ft. 6 in. to 7 ft. in the ground, the hole 6 in. deeper; concrete to be rammed round as above. Concrete filling to be thoroughly tamped. The setting to be to the satisfaction of the company's engineer.

Trolley Wire.—All trolley wire to be .325 in. in diameter hard-drawn copper; to have 98 per cent. conductivity of pure copper, and to be furnished in lengths not less than $\frac{1}{2}$ mile on each reel. Diameter of trolley wire not to vary more than .0004 in.; breaking strain to be at least 56,000 lb. per square inch, or equal to about 4,980 lb. for a No. 0 B.S. hard-drawn wire.

Insulation.—Insulating material to be thoroughly homogeneous, and moulded under pressure; to be non-absorbent, impervious to water and weather, and resonant when struck, and of most approved and recent style and construction. Straight line, pull-off, bracket-arm, bridge, car-house insulators, &c., to be of "West End" or "Armourclad" type. Metallic parts to be of gun-metal or malleable iron. Insulating bolts to have steel centres. Insulation to be completely protected from weather or blows by metallic skirt. Parts to be interchangeable throughout. Bracket arm sleeves to be galvanised iron made in halves, held together by four bolts. Double insulation to be used at all points.

A proper and workmanlike arrangement of strain insulators, terminals, &c., to be followed throughout.

Section insulators to be erected every half mile. These and all frogs and crossings to be "straight underrunning."

No mechanical ears to be used in construction. All ears to be of bronze metal with groove tinned ready for soldering, and to fit a trolley wire as above. Ears to be not less than 15 in. long.

Insulators (if of malleable iron) supporting trolley wire to be painted with "P. and B." or other waterproof, acid and alkali resisting, highly insulating and rapid-drying paint.

Span Wire.—Span wire to be of galvanised steel, seven-strand galvanised steel cable, having total diameter of $\frac{1}{4}$ in. and breaking strain of 1,600 lb. In places where exceptional

strains are incurred, seven-strand $\frac{5}{16}$-in. cable having breaking strain of 3,360 lb. is to be used, or if preferred a galvanised single steel wire No. 4 B. and S., or No. 6 B.W.G. may be used.

Erection of Trolley Wire.—To be erected so that during the coldest weather the stress to which it is submitted shall not exceed 1,700 lb., the breaking strain of the trolley wire being taken at 4,980 lb. It is to be soldered to the ears by a solder of two parts tin to one part lead. Under no circumstances will use of blow-lamp be permitted. Where hung from span wire, sag of span wire not to exceed $\frac{1}{30}$th of the span. All splices to be effected by means of a 15-in. splicing ear at points of suspension. Splicing tubes will not be tolerated. Section insulators to be inserted every half mile. Section insulators may (with consent of engineer) be bridged over by fuses. All frogs to be "underrunning." Distances between supports not to exceed 150 ft., unless specially allowed by engineer, average to be from 120 ft. to 140 ft. Lightning arresters to be erected every half mile, to be easily accessible, to work at least ten times in succession before requiring attention, to be furnished with automatic device whereby the current on the main line is prevented from following the lightning discharge and causing short circuit on line. Feeders to be connected to trolley wire every half mile through "quick-break" switches. These to be fixed in cast-iron boxes attached to pole or placed in watertight and easily accessible box or pillar. Anchorages to be provided every half-mile, and on either end of every curve. If required, guard wires to be erected wherever telephone or telegraph wires cross the trolley wire. Guard wires to be galvanised steel wire .134 in. in diameter, and two wires to be carried over each trolley wire at a height of at least 18 in. above the trolley wire. Guard wires to be suspended by means of insulators, which are to be of the same material as that adopted for line work. Rectangular wooden strips may be fixed on the top of the trolley wires instead of guard wires by means of clips 3 ft. apart. These strips to be ended by a bent-up piece of brass wire to prevent telephone or other wires which may fall slipping off on to trolley wire. Or bare telegraph or telephone wires at the place where they cross the trolley lines may be replaced by insulated wires, or else spans may be formed by means of separate lengths of wire fixed by hooks at both ends of the span, so that should one of these spans break, the span will come down bodily and prevent any danger of fire in the telephone or telegraph wires. Where large numbers of wires cross the trolley line, wire netting, supported from insulators, to be fixed to telegraph or telephone posts, destined to catch up any broken wire and prevent its falling into the street.

Feeders.—Underground feeders to be lead-covered, to be laid in lengths not exceeding $\frac{1}{2}$ mile, and connected in junction-boxes, so that any section can be insulated for testing. An insulated voltmeter wire to be run from power station along line and to be connected to rails at ends of sections, the object of this wire being to measure the fall of potential along the return circuit as required by the Board of Trade. Overhead feeders up to .409 in. in diameter to be of solid hard-drawn copper, to be covered with weather-proof insulating compound, to be furnished in lengths not less than $\frac{1}{2}$ mile each. Above .409 in. stranded cables to be used, to be carried by brass cap feeder insulators of same material as line insulation, to be hung so as to have no greater sag than trolley wire, and to be free of kinks.

Return Circuit.—Soft-drawn copper bonds to be used throughout, made in one piece, without brazing or soldering, and having a conductivity of at least 98 per cent. of pure copper. To be of such number, section, and construction as to fulfil the following conditions. Each rail joint to be bonded with bonds constructed so that contact area of copper within web of rail is at least six times sectional area of copper wire used. Bonding to be so calculated that current density of return circuit shall not exceed 50 amperes per square inch when average number of cars are in operation. Holes in web of rail to be drilled with twist drills or punched at mill. If the latter. holes are to be made $\frac{1}{16}$ in. smaller than required for bonds, and this $\frac{1}{16}$ in. to be reamed out when the rails are in position and just before bonding.

Quality of workmanship to be such that rail bonds, together with contact surfaces, shall not add to the calculated resistance of a solid rail of equal length, more than 25 per cent. There shall be cross bonds of similar type between rails every 120 ft. All bonds and crossings to be completely bridged by long bonds of same type, and to be connected by short bonds to rails on either side. All bonds, after being fixed in the rails, to be painted with "P and B" compound, or other equally good material, of high insulating properties, acid and alkali proof and non-corrosive, and which dries rapidly. Bare return wires in no case to be used. If the rail return is not sufficient to carry the current, insulated feeders to be laid wherever necessary. Connections to earth plates or water-pipes will not be tolerated, except where required by Board of Trade.

Specifications of Power Station.

Boilers.—Water-tube boilers are very much in favour, although Lancashire boilers have been used with success. Certain engineers prefer tubular boilers of the marine type. On the Continent a combination of the two has proved fairly successful. In large installations automatic stokers are used to advantage, but where these are used mechanical coal conveyors should also be adopted.

Steam Engines.—The very rapidly varying loads which have to be borne by the engines of traction plants, and the necessity for maintaining uniform speed and preventing the engine racing when the load suddenly varies from a maximum to nothing, has caused engine builders in America to design and develop special types. These engines may roughly be classed as high-speed and low-speed engines. The following specification may serve as an example of the typical engine built for traction purposes.

Workmanship and Materials.—Workmanship, finish, fitting, and materials to be first-class. Forgings to be of best open-hearth steel, or hammered iron. Castings to be of best quality as regards strength, wearing qualities, and smoothness. Castings subject to wear, such as cylinders, guides, pistons, &c., to be poured from special heats of a mixture containing charcoal iron, graded according to size of casting, to secure proper hardness and closeness of grain. These to be separate and distinct heats from which are poured frames, wheels, and other heavy parts. Engine to be made to gauge, and interchangeable in all parts. Flat surfaces to be scraped to surface plates, and surface and cylindrical grinding to be used where advantageous.

Guarantee.—Workmanship and material to be first-class, and duplicate of any part defective within one year to be supplied free. To regulate from no load to full rated load within 2 per cent. variation of speed. To run in without undue heating or vibration.

Cylinders.—Cylinders to be cast of charcoal iron as above. To be neatly covered with iron lagging, inclosing thick layer of non-conducting material. To be provided with combination relief valve and drip-cock of large diameter at each end, to open automatically at any pressure.

Jackets and Receiver.—High-pressure cylinder to be steam-jacketed, and a receiver of large capacity to be provided between cylinders. Receiver to be filled with heating coils containing steam at boiler pressure. High-pressure jacket and coils to be piped in series, steam passing through in the order named. The water condensed in jackets and in coils to be returned to boiler.

Connecting Head and Metallic Packing Sleeve.—Connection between cylinders to be such that low-pressure head can be removed without disturbing high-pressure cylinder. Between cylinders, the piston-rod to run in a packing sleeve or tube, babbited or bored out to fit. In horizontal engines this tube to be provided with self-adjusting block.

Valves and Valve Gear.—Cylinders to be provided with valves of piston type of standard form. Valves to be provided with adjustable seat to prevent leakage. Valve gear to be constructed in substantial and durable manner, and made adjustable for wear. Low-pressure valves to be driven by fixed eccentric. Eccentric-rod to have bronze end with quick taper key adjustment and unhooking device for larger sizes. Eccentric strap to be lined with babbit, hammered in and bored out.

Governor.—Arrangements to be such that opposing forces of centrifugal weights and springs cause no friction in governor mechanism. Governor to be accurately fitted. All to be made of tool steel, hardened and ground, turning in bearings bushed with phosphor bronze.

Piston, Piston-Rod, and Stuffing-Box.—Pistons to be made very light and strong, and to be secured to piston-rod by nut and taper. Pistons to be provided with cast-iron packing rings, returned after being sprung to size of cylinder, so as to touch all round and wear equally. Piston-rod to be of open-hearth steel, running through deep stuffing-box with babbited gland. Rod to touch head, which must be bored large, and brass ring fitting rod in bottom of stuffing-box to prevent escape of packing to interior of cylinder.

Framing and Extended Foundation Box.—To be heavy and massive, stiffened with internal ribbing.

Guides, Crossheads, and Crosshead Pin.—Guides to be made of charcoal iron, and the lower guides to be separate from frame and adjustable by liners. Crosshead to be of locomotive type, and together with the crosshead pin to be made of one piece of charcoal iron.

Connecting-Rod and Boxes.—Connecting-rod to be of forged steel, provided with gib and key ends. Crank and crosshead pin boxes to be lined with babbit, hammered in and bored out. Body of connecting-rod to be of larger section than piston-rod. Straps, gibs, and keys to be carefully proportioned to secure strength and ample bearing surface, to prevent rod loosening under work and frequent adjustment.

Main Bearings.—Main bearings to be provided with quarter boxes, each backed up for its entire length by solid adjustable wedge. Bearings to be lined with babbit metal, hammered in and bored out.

Crankshaft.—Crank-pin, webs and shaft to be made one solid piece of open-hearth steel. Suitable counterbalance to be provided, securely attached to crank webs. Bearings and pin to be carefully lead-lapped to them perfectly true.

Adaptation for Direct-Driven Dynamo or Generator.—Engine to be designed throughout with a view to the requirement of running a direct-driven dynamo with the armature mounted on shaft of engine. Armature occupies the position of one of the belt wheels on ordinary belted engines. Other wheel to be of extra weight, carefully designed, turned true and balanced. Shaft to be of extra length, sufficient to run through armature and an out-bearing. Bearings to be made of extra size. Engine sub-base to be arranged to extend under and support dynamo and out-bearing.

SPECIFICATION OF DIRECT-CONNECTED RAILWAY DYNAMO, OUTPUT OF 150 KILOWATTS AT 200 REVOLUTIONS.

Armature to have rigid cast-iron spider suitable for keying to a 10-in. shaft. Laminations to be of best quality soft iron, keyed to spider once if ring of laminations is continuous. If built up of segments, each segment shall be dovetailed by projections into the iron core at least twice in its lengths. Core to be of projection type. Conductors, of which there shall not be more than four in a slot, to have a cross-section such that current density at full load shall not exceed 1,500 amperes per square inch. Outside conductors, at ends of armature, shall be securely bound to a cylindrical surface. Conductors shall extend from end to end of armature without jointing, and shall be insulated from end to end with not less than $\frac{1}{10}$ in. insulation between conductors and iron core.

Commutator.—To be self-contained with armature. Segments to be built up upon a rigid spider carried from spider of armature, so that armature and commutator without shaft constitute one part. Segments not to be less than 2 in. radial depth, and to be of hard-drawn copper. Insulation to be mica throughout not less than $\frac{50}{1000}$ in. thick, and between segments and end rings not less than $\frac{1}{8}$ in. Commutator shall have not less than 50 segments per pole, and be designed so that groups of segments may be removed without disturbing remaining groups. Brushes to be of carbon. Current density between brushes and commutator at full load shall not exceed 35 amperes per square inch. Brush-holder to be of such type that brushes are easily replaced, and tension easily adjusted.

Field Magnets.—To be of best soft steel with internal projecting cores. Magnet frame to be rigid in design, and cores to be held in place by bolts and easily removable. Coils to be wound upon solidly constructed spools with brass end. Shunt coil to be wound of wire circular in section. Series coil to be wound up of strip copper, and connections between the different coils made so that current density where connections are bolted together shall not exceed 150 amperes per square inch at full load. Series coil and magnet frame to be so designed that voltage may be increased by equal increments from 500 to 550 volts.

Temperature.—No part of machine shall after eight hours' test at full load exceed temperature of atmosphere more than 30 deg. Cent.

Insulation of armature conductors, field magnet conductors, and commutator, shall be of such quality and workmanship as to withstand 5,000 volts alternating for half an hour.

Efficiency.—Commercial efficiency, including excitation, shall not be less than 94.5 per cent. full load, or 88 per cent. including excitation at quarter load.

General Performance.—Machine must withstand without dangerous sparking or heating such changes of load as momentarily happen in tramway practice between no load and 50 per cent. overload. Commutator must present at all times a clean and smooth appearance, and must wear away evenly and not blacken in uneven and irregular fashion.

SPECIFICATION OF MOTOR TRUCK.

Trucks to be of cantilever extension style of construction. Side frames to be constructed of "soft steel" bars secured to semi-steel pedestals by hot rivets, and portions to be supported from underneath by trusses attached to the extreme end portions of the side frames and to the base of the pedestal by means of springs, and so secured (in pockets) that the rivets holding them in place are not subjected to shearing strains. The main side bars to be also so secured in accurately fitted grooves in the sides of the pedestal arms, that the downward strain comes directly upon the pedestals and not upon the rivets. The upper cross-section of the pedestals to be cylindrical in shape and hollow, and fitted with double coil springs, resting upon the

iournal boxes and sustaining the entire weight of the truck frames, so as to relieve them, and also the motors suspended therefrom, of all shocks and concussions. The opening at the bottom of the pedestals for removing the journal boxes to be provided with removable cast-steel wheel pieces accurately machine fitted to the opening in the pedestal, and secured in place by removable bolts provided with split pins. When in place, these wheel pieces to make the cantilever truss continuous from end to end. The side frame to be provided at its top with a continuous bar provided with recesses for receiving the spring bolts, so that they can be removed without jacking up the car body. The springs for supporting the car body to consist (for the entire truck) of four elliptical and twelve coil springs, so combined and graduated that the weight of the car comes first upon the elliptical springs, and as the load increases the spiral springs come into play. The car must ride easily whether it be light or heavily loaded, and the springs not be overloaded. The end spiral spring bolts to be provided with-under-tension springs to prevent pitching, held in place and adjusted by check nuts on each end of the spring bolts, which are to be provided with split pins. Length of solid forged top frame to be 14 ft. Length of spring base (centre to centre of springs) to be 12 ft. 8 in. Length of wheel-base (centre to centre of wheels) to be 6 ft. 6 in. Gear to consist of a yoke or pedestal to be constructed with a cylindrical aperture in its upper cross-section, into which are inserted graduated double coil springs, which rest upon the journal boxes and support the entire weight of the truck frame, yoke to be secured in the grooves of the extended side arms of the pedestal by hot driven rivets. The grooves in the arms of the pedestal to be fitted to correspond accurately with the dimensions of the main horizontal steel bars of the side frames, which are to be inserted in the grooves and held in place by rivets. The base of the pedestals to be provided with a removable repairing piece secured in place between the jaws of pedestal by bolts, and to be easily removable. Bearing parts to be accurately machine fitted to correspond to the bearings of the pedestal, which are also to be machine fitted. To be provided with a cylindrical projection, fitted loosely into a cylindrical opening in the bottom of the oil box. The journal box to be so constructed that oil or grease may be used as desired. To be absolutely dust-tight. The bearings for the cover to be machine fitted, and between the bearings and the cover to be inserted a packing of leather. To be provided at the back end with a dust-tight packing that rests upon the axle. Rigid steel collars to be pressed upon the axle by hydraulic pressure of ten tons, and carefully machined so as to give the proper distance for the motor bearings. These rigid collars are to be provided with flanges, to which are bolted sectional washers constructed in halves. The brake beams to be manufactured from the best quality of wrought-steel bars, carefully machine fitted. The connecting bolt to be machine turned and case-hardened to insure accurate fit, and prevent wear. The leverage to be 10 to 1, and sufficiently powerful to handle a 30-ft. (over all) car with ease. The brake guides to be provided with removable repair pieces to take up lost motion as they become worn, so as to prevent noise. To be provided with position pull-back coil springs for releasing the brake shoes from the wheels. The brake shoes to be furnished with the Christy head, and to be so constructed as to be interchangeable and easily removed without loosening any bolts. Each truck to be fitted with an adjustable life and wheel guard at either end, so constructed as to be easily adjustable at any desired height from the truck. All trucks to be fitted with wheels of approved style and shape of tread and flange.

Specification for Street Railway Motors.

Preference will be given to motors of the multipolar type, carrying drum armatures, though this clause is not intended to bar Gramme ring armatures. There must be sufficient iron or steel included in the magnetic circuit to prevent either armature or field heating

excessively, and pole-pieces are to be so designed as to leave the neutral field sufficiently broad, in order that the motor may run in either direction, and and with any load, without undue sparking. Motors to be capable of exerting 800 lb. to 1,000 lb. horizontal effort at the periphery of a 33-in. wheel, at a speed of eight miles an hour. To be of the ironclad type, entirely boxed in so as to be water and dust proof, to be provided with a suitable door to allow of easy access to brushes and commutator. Weight of motor complete with casings, gear, and gear case, not to exceed 2,000 lb. Vertical dimensions of motor to be under 2 ft. To be of best material. Motor to be supplied with self-feeding carbon brushes, which shall not spark at any load. All parts of motors, attachments, and appliances to be interchangeable. Where two motors are used per car, the load to be equally distributed. The machines to work in perfect unison. Cost of repairs and renewals on motors and apparatus, including gears and pinions, not to exceed .125 pence per car mile.

Bearings to be of ample dimension and of the self-lubricating type.

Armature to be of the ironclad type, the coils being carried between projections, to be formed and interchangeable; to be insulated with mica and asbestos, and so finished as to be waterproof. End connections to be securely clamped by means of conical nuts or other approved construction. Commutator to have not less than twenty-five segments per pole, and to be of hard-drawn copper and insulated with mica throughout. Armature to be so insulated as to withstand 5,000 volts alternating between circuit and core.

Magnet Coils to be formed and interchangeable, and to be insulated with asbestos so as to be water and fireproof. Coils to be insulated so as to withstand 5,000 volts alternating between coil and frame.

Gears.—Reduction not to exceed 4.8. Pinion to be of steel, and gear of cast iron or steel. Face of gear not to be less than $4\frac{1}{2}$ in. Gears to be placed in oil and dust proof cases carried from motor frame so as to prevent rattling or jarring loose. Gear and pinions to be best wearing material, and teeth to be machine cut.

Efficiency.—Motor to be so designed that under ordinary working conditions consumption of energy per car-mile for average running speed (or at least six miles an hour including stops), shall be less than $\frac{9}{10}$th of Board of Trade unit, and the motors shall be so designed as to fulfil this last condition permanently without dangerous heating or sparking, or causing damage to commutator. When tested, the commercial efficiency at its normal load and average speed shall be at least 80 per cent.

Nuts and Bolts must be provided with some self-locking device.

Station Fittings.

Switchboards.—The latest practice in the construction of switchboards cannot be described better than by a summary of a standard specification.

The backing shall be composed of highly polished slate absolutely free from metallic veins. No combustible material to be used in making up of the backing or its foundations All connections shall be clamped connections made at back of board. Front to carry only instruments and switches. Equalising switches to be on marble slabs not erected on the switchboard, but set up next to each generator. Each generator to have a separate switchboard panel, and a separate panel to be furnished for the feeder circuit. A separate panel must also be supplied to carry the instruments called for by Board of Trade rules. For lighting the station, and for any motors which may be run in the station, a separate panel must be supplied.

Generator Panels.—The following instruments are to be on each panel:

Two main quick-breaking switches connected to the two bus-bars at back. A magnetic circuit-breaker, with device for blowing out the arc, shall be fixed on the negative pole of the generator between the negative switch and bus-bar. An absolutely dead-beat ammeter, with a scale reading from nothing up to the highest output which the generator is capable of giving without burning out, shall be provided for these panels. This instrument to be of such a type that its scale divisions are equal. A rheostat in the shunt field shall also be supplied with each panel, and shall be such that the voltage of the machine can be brought down when at normal speed to at least 300 volts. A shunt with at least 500 ohms resistance shall also be provided for short-circuiting the shunt field when a generator is put out of circuit.

These rheostats by preference to be of the iron strip type, and not to consist of coils of wire. The 500 ohms resistance to be provided with a switch worked from the front of the switchboard. A plug attachment to be supplied, enabling the station voltmeter to be put on to the terminals of each generator. A recording wattmeter to be put on each generator panel. A lead fuse to be connected to the positive and negative terminals of the generator and fitted on it, and an alarm connection to be made between the circuit-breaker on each generator panel and an electric bell, in such a way that when one circuit-breaker comes out the alarm bell is rung, and goes on ringing till the attendant cuts it out. A lightning arrester of approved type shall be fitted on the positive lead of each generator. This lightning arrester to be fitted with choking coil, and to be of a type which will act several consecutive times without attention, and to be furnished with an arrangement making it impossible for the main current to follow the lightning discharge and thus cause a short circuit. If required, lightning arresters shall also be supplied to the feeders connecting the return circuit to the switchboard. (Should the locality be liable to very numerous and heavy thunderstorms, a water tank lightning arrester should also be inserted in the machine circuit during such storms.)

Feeder Boards.—Each overhead line feeder to be connected to the feeder board by means of an automatic circuit-breaker of the same type as that used on the main board panel. For feeders carrying very light currents, with the consent of the engineer, fuses may be substituted. These fuses to be arranged in such a way as to make an arc impossible, and to be easily replaceable while the current is on. The feeders to be connected to the main bus-bar by means of quick-breaking knife switches. An ammeter to be in the circuit of each feeder, and to have a device whereby the maximum current output is recorded. For large stations with heavy feeders, a recording wattmeter to be put in each feeder or group of feeders. A main ammeter to be supplied on which the total current output is constantly shown. Also a wattmeter recording the total energy output. A dead-beat voltmeter of the same type as the ammeter supplied to be in the working circuit. These last three instruments and a station clock to be erected on a panel by themselves. Another voltmeter to be supplied, and so connected to a plug that it can be put on the terminal of any generator when being run up to speed and pressure for putting into parallel on the line.

Board of Trade or Leakage Board.—To be erected on this panel: A recording ammeter reading up to 10 per cent. of the average output of the station; a recording voltmeter reading from 0 to 10 volts; a sensitive ammeter with two scales, one capable of indicating from $\frac{1}{50}$th to 2 amperes, and the other from $\frac{1}{2}$ to 10 amperes, a suitable switch or plug being fitted to the instrument so as to alter its connections and to enable its being read on either scale; a current indicator showing direction of current, whether from earth-plates to rails or *vice versâ*.

The earth-plates prescribed by the Board of Trade are to be connected to suitable switches on the switchboard, enabling either of them to be put in circuit with the recording

ammeter and the rail return. The overhead line must also be brought to a switch by means of which it can be put in circuit with the low-reading ammeter and with the generators when the latter are running and all the cars are off the line, so as to test insulation resistance. If required, the main feeders must also be able to be connected to this low-reading ammeter. This board to carry any further instruments which may from time to time be called for by the Board of Trade.

All main voltmeters and ammeters to have illuminated dials.

Connections.—All cables leading from the switchboard and generators to be best quality, to have an insulation resistance of at least 1,000 megohms per mile, and to be laid in the waterproof trenches which connect the dynamos to the switchboard. They are not to cross unless absolutely necessary, and where they cross must be laid in casing. In the trenches cables are to be supported every 4 ft. on porcelain insulators fixed to wooden frames. All cables and woodwork when completed are to be thoroughly coated with highly insulating, and water, acid, and alkali-proof compound, such as "P. and B." Switchboard to be at least 4 ft. from the wall. All swithboards are to rest on hard wood foundations, and under no circumstances must positive and negative connections cross each other. All Board of Trade rules to be carefully complied with.

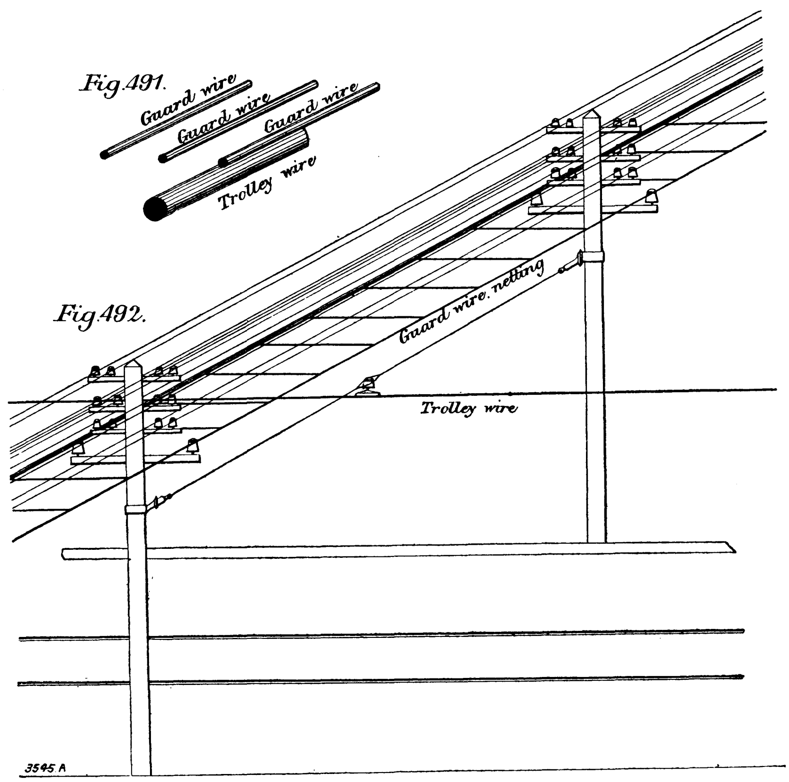
Testing-Room.—A battery of 150 Leclanché cells to be supplied. (It is well to charge these cells with a solution of about one-fifth of the strength generally used, as this diminishes the creeping effects of the salt, and as the battery is always used in series with a very high resistance, the current required is always exceedingly small.) This battery to be placed on a shelf completely and thoroughly insulated from all its surroundings. A brick or concrete block to be sunk within the test-room until solid ground is reached, and to be at least lower than the foundations of the building, and entirely disconnected from them. The top of this pier to be covered with a stone slab laid true, and should vibration be felt this stone must be laid on a layer of felt or rubber. Pier to be 6 ft. long, and 2 ft. wide. A Thomson reflecting galvanometer to be supplied, with a total resistance of at least 10,000 ohms, and with coils which can be differentially connected if desired. (Should trouble be anticipated from induction, a bell-shaped cast-iron shield from 4 in. to 5 in. thick should be supplied, furnished with a slit to allow the light to be reflected from the mirror of the galvanometer.

Also to be supplied :

A Deprez D'Arsonval galvanometer with a resistance of not less than 2,000 ohms. Lamps and scales for both instruments. A 100,000-ohm coil in four divisions, a shunt of $\frac{1}{9}$th, $\frac{1}{99}$th, and $\frac{1}{999}$th for both galvanometers. Two ordinary portable plug Wheatstone bridges of 10,000 ohms, with coils ranging from .1 to 10,000 ohms. A condenser, two standard Clark cells, and a standard megohm. Three double reversing keys, a single key, and a discharging key of approved type. The room to be well lit, and the windows furnished with opaque blinds. Wires to run from a small switchboard in the test-room, fitted with terminals, to the various feeder cables, generators, &c. These wires to have an extremely high insulation resistance, and to be run on insulators.

Protection of Telephone and Telegraph Wires.—There are two dangers from which telephone and telegraph wires must be protected when in the neighbourhood of trolley lines. The first, and that most easily remedied, results from the breaking of wires above, or which cross, the trolley wire. The means adopted to prevent damage from this source are based on two principles. The oldest method, and one now

falling into general disuse, was to provide some device whereby a fallen telephone or telegraph wire was prevented from coming into contact with the trolley wire. Americans originally adopted galvanised steel guard wires, similar in size to the ordinary telegraph wires, and suspended three such wires over every trolley wire at a height varying from 12 in. to 24 in., and distant from each other about 2 ft. These guard wires were suspended from special insulators similar in type to those used for suspending the

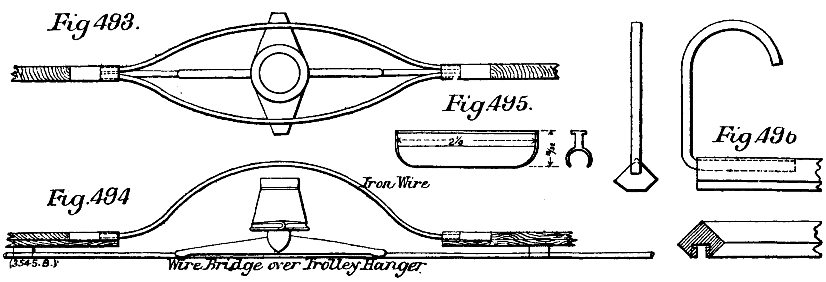


GUARD WIRE NETTING.

trolley wire, but smaller. Fig. 491 shows this arrangement, which has several grave disadvantages. It necessitates a great increase of overhead wires, very disagreeable to the eye. The guard wires are necessarily not strong, and when a broken telegraph or telephone wire falls, it often happens that the guard wires also break and fall into the street, endangering the public. It has frequently occurred that a telephone wire falling from some height has whipped round the guard wires, and got caught in the trolley wire. It may safely be said that experience has proved that instead of being a safeguard, such wires are rather the reverse. Where a

very large number of wires cross the track, a very much better system is to form a network of wire and to stretch this underneath the wires where they cross the track. Fig. 492 shows such an arrangement.

A system largely adopted on the Continent, but which possesses the great disadvantage of making the trolley wire most conspicuous, is shown in Figs. 493 to 496. It consists of a pentagonal wooden strip fixed to the top of the trolley wire by means of clips (Fig. 496) which are fitted into grooves cut at distances of from 3 ft. to 6 ft. in the wooden strip. These strips are usually made in lengths of from 20 ft. to 30 ft., and are fitted together by means of little brass sleeves. Where insulators are encountered the strips are cut off, and the insulator is protected by means of two wires carried over it, the ends of which are attached by a metallic clip to the wooden strip. As a protector, this system is fairly efficacious, but it makes



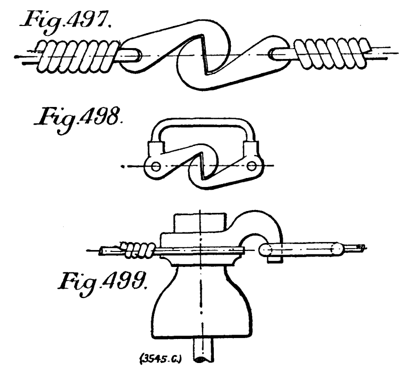
TROLLEY WIRE GUARD.

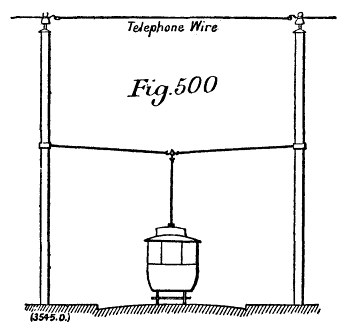
the trolley wires look extremely heavy, and if a telephone or telegraph wire falls from a great height, it is likely to whip round underneath, and thus come in contact with the trolley wire, notwithstanding the strip.

A system proposed in Germany, and which would seem much more efficacious, is shown in Figs. 497 to 500. It consists in making up the telephone and telegraph wires at crossing points of short sections, and so erecting them that the moment the tension of the span is slackened the whole span falls down into the street. The sections are so short that one piece cannot reach from trolley wire to ground. In the case of telephone wires where a perfect contact is essential, the system shown in Fig. 498 is adopted. A light lead wire is firmly connected across each joint, and while securing perfect electrical contact, will give way the moment it has to support any strain.

The trouble which may result from a telephone wire coming into contact with the trolley wire is either by causing shocks to persons on the

ground who may come in contact with it, or by fire, a danger which in several cases in Germany has been found to be very real. According to Dr. Strecker, the chief engineer of the German Telegraph Department, there have been reported, since 1891, 5, 4, 2, 15, 31, 19 cases, the last figure referring to the first four months of 1896; altogether 76 cases, in 70 of which telephone stations and apparatus were damaged by strong currents, which in 61 of these cases came from electric railways. No information exists about mishaps in which the protective appliances prevented all disturbance. In 40 instances the trolley wire was capped by wooden strips; guard wires were used in 10 cases. Protective appliances were absent in 8 of the 15 cases for which electric railways were not responsible. In most instances the damage done to the coils was very

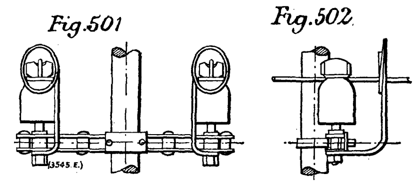




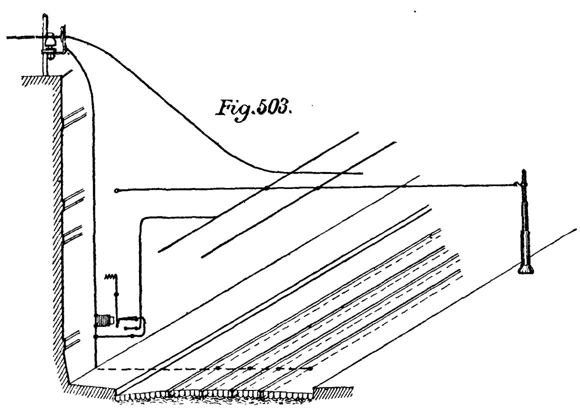
PROTECTIVE DEVICES FOR TELEPHONE WIRES CROSSING TROLLEY LINES.

slight; two fires, only one serious, have been reported. Experiments have been conducted for years with a view of ascertaining whether the delicate printing and writing telegraphs, and the telephone instruments, which cannot stand more than 0.12 or 0.20 ampere, could be protected. Many devices have been tried; very fine wires proved mechanically too weak, and too much affected by corrosion and by atmospheric currents. Further experiments of a satisfactory kind were hence made with wires which can bear about 1 ampere; one wire more particularly recommended will take 0.5 ampere and sparks of 0.07 millimetre length. Delicate appliances will hence have to take care of themselves. Fuses of these types of 4 centimetres (1.6 in.) length arc when they suddenly receive 500 volts, even if inclosed in fine glass tubes. But if the tubes are closed by cork discs or sealing-wax—not by metallic caps—no arcing will occur. The telephone companies now always insert a very delicate fuse in every one of their

circuits, the fuse generally consisting of a very thin and wide piece of tinfoil pasted on a piece of card-board; such a fuse will always give way the instant a current of any strength passes through it. To make sure of this fuse going the instant the telephone wire touches the trolley wire, a device has been adopted which is shown in Figs. 501 and 502, consisting of a metallic loop connected to earth through which the telephone wire passes, and with which it is bound to come in contact in case of breakage. There still remains, however, the danger of shocks.



Telephone Wire Earthing Device.



Telephone Earthing Device.

The telephone wire, when it comes in contact with the trolley wire and earth, generally fuses at the latter point and hangs free from the ground. When the earth connection is severed between telephone wires and ground, the magnetic circuit breakers at the central station when closed do not show any short circuit, and there is no way of ascertaining that a wire is hanging on the trolley line to the danger of passers-by. Mr. Ulbricht, of Zwickau, experimented in this matter, and has now applied a device to the trolley line which is said to be working satisfactorily. At the instant a telephone wire falls and comes in contact with the trolley wire, an electro-magnetic relay is brought into action which causes a permanent short circuit on the

trolley wire, and prevents the automatic circuit breaker being replaced in the power station until the fallen telephone wire has been removed. (See Fig. 503.) The connection between the telephone wire, the trolley wire, and the loop connected to earth through which the telephone wire passes, causes a permanent contact, or, in other words, a short circuit on the trolley wire until the broken piece of telephone wire has been removed.

The second danger to which telephone circuits especially are liable is that due to induction from the variable current in the trolley wire, and secondly to the leakage or current which may be set up where earth returns are used. The former trouble can be nearly entirely got over by providing the telephones with a double metallic circuit. All properly put up telephone circuits should be entirely metallic, and until this is the case a good telephone service will not be possible. This opinion has frequently been expressed by Mr. W. H. Preece, chief engineer to the Post Office Telegraphs.

The disturbance is proportional to the strength of the current, or, more properly speaking, to the impulse of the current, and it is inversely proportional to the square of the distance between the trolley and telephone lines. It has been found in practice that if the telephone wires are more than 200 yards from the trolley line, but little trouble is experienced. The less sudden the variations of current in the trolley wire, the smaller will be the disturbances in the telephone line. The chief cause of variation in current is the variation in the resistance of the circuit due to the contact between the trolley and the trolley wire, between the motor brushes and the commutator, and between the wheels and rails, and also the sudden difference of resistance caused when the car goes from one rail to another, when the bonding is bad or insufficient. The first difficulty is overcome by having a properly built trolley line with a good trolley wheel and proper springs supporting it against the trolley wire. Some have expressed an opinion to the effect that sliding contacts are better than rolling contacts. This does not seem to be the case, as heavy sparking is often observable between the sliding contact and the trolley bar. Whenever sparks occur the resistance between trolley wire and car wiring is suddenly increased, the current having to jump an air space to get to the trolley. When motors are so constructed as to have a sufficient number of commutator segments, and when little or no sparking occurs at the brushes, little disturbance will arise at the motor. Probably the worst disturbances are caused by a varied resistance between wheels and rails, and it is evidently extremely advantageous to keep the rail return as perfect as possible and the rails clean.

In case of a double telephone line or metallic circuit, the proximity of a trolley line will produce in the two wires disturbing currents which will annul each other. Thus no disturbing influence will be noticeable in the telephone apparatus. Where the current on the trolley wire is very heavy, even this precaution is not always sufficient, and the two lines must be put at such a distance from each other as to insure the noise being sufficiently subdued. This distance depends upon the distance over which the telephone wires run parallel to the trolley wires. The disturbance due to the induction is the more difficult to overcome. The only possible way seems to be the use of a double circuit for the telephones, and to prevent these circuits, as far as possible, from running parallel to the trolley wires.

It is an interesting fact that under apparently the same conditions one trolley line will cause a very much greater disturbance in a telephone circuit than another. This has specially been observed by Dr. Wietlesbach, the chief engineer of the Swiss Telephone and Telegraph Department.

The conclusions to be drawn would seem to be that where a trolley line is properly constructed, that is to say, where heavy returns and proportionally heavy bonding and, if necessary, insulated return feeders, are adopted, and the track so built as to be perfectly solid and, as far as possible, insulated from the ground by a concrete foundation, and earth plates of no description used, little or no disturbance is to be feared in telephone circuits where these are properly constructed with complete metallic circuits.

CHAPTER XXXI.

ACCOUNTS AND THEIR CLASSIFICATION.

A PRECISE and logical classification of accounts is of the greatest importance in street railway practice, especially where mechanical traction is employed. So far but little uniformity exists in the methods of classification adopted by the various street railway companies. This is to be regretted, as it renders it most difficult, if not wholly impossible, to institute any comparison between the economy of operation of the different systems on roads worked under similar conditions.

Not only does a careful classification furnish information of great value to directors, shareholders, and the general public, but it enables the responsible executive to determine at a glance where economy may and should be effected, and whether the plant is being worked to the best advantage. The importance of a uniform system of accounting is at once perceptible, as it stimulates a healthy competition between operating companies and managers to run as cheaply as possible, and compels the makers of plant and equipment to develop their apparatus as highly as possible. Moreover, the parts of the various departments of a tramway company are put upon their mettle, and must endeavour to reduce to a minimum those items of expenses for which they are directly responsible.

The greater the system, the more detailed should be the accounts, as in large concerns very small economies on comparatively petty items may mean a considerable saving in expenditure.

The subdivision adopted by the West End Road of Boston, one of the oldest and best managed of electric railways, is given in Table CXVII.

TABLE CXVII.—West-End Street Railway Company.—Schedule of Operating Expenses, Horse and Electric Lines.

General Expenses.

Salaries, Office and General Expenses.

1. Salaries, president, vice-president, and clerks.
2. ,, general manager and clerks.
3. ,, treasurer, paymasters, and clerks.

4. Salaries, receiver, clerks, and collectors.
5. ,, auditor and clerks.
6. ,, purchasing agent and clerks.
7. ,, and expenses, storekeeper and clerks.
8. Supplies and expenses, general offices.
9. Telephone repairs and expenses.
10. Fare registers.
11. Stationery and printing.
12. Miscellaneous expenses.

Legal Expenses.

13. Salaries and expenses of attorneys.
14. ,, claim agent and clerks.
15. Expenses claim department.

Inspection.

16. Services of inspectors.
17. Inspectors' fares and expenses.

Insurance.

18. Fire insurance premiums.
19. Indemnity insurance premiums.

Rents.

20. Rent of land and buildings.
21. Rent of other roads. (Trackage only.)

MAINTENANCE OF TRACK AND BUILDINGS.

Maintenance of Track.

22. Superintendence, engineering and general expenses, road department.
23. Labour, repairing track.
24. ,, paving track.
25. ,, of teamsters, road department.
26. ,, of watchmen, ,, ,,
27. Timber and ties.
28. Rails and fastenings, turntables, transfer tables, frogs and switches.
29. Paving blocks.
30. Sand, gravel, and cement for track repairs.
31. Maintenance of carts and vehicles for track repairs.
32. ,, other track tools and equipment.
33. Use of horses for track repairs.
34. Miscellaneous expenses of track repairs.

Maintenance of Buildings.

35. Superintendence and general expense of buildings department.
36. Repairs of stables.
37. ,, horse-car houses.
38. ,, electric car houses and repair shops.
39. ,, other shops.
40. ,, miscellaneous buildings.
41. ,, tenements.
42. Repairs and renewals of tools and machinery in building department.
43. ,, of power stations (exclusive of equipment).

Maintenance of Equipment.

Maintenance of Cars and Vehicles.

45. Repairs of box horse-cars.
46. ,, open horse cars.
47. ,, box electric cars.
48. ,, open electric cars.
48 A. ,, trucks for electric cars.
49. Miscellaneous car repairs.
50. Repairs of electric snow equipment.
51. ,, snow ploughs and other snow equipment.
52. ,, carriages, waggons, and vehicles.

Maintenance of Shop Equipment.

53. Repairs of machinery, tools, and equipment of car shops—electric and horse.

Maintenance of Horse and Harness Equipment.

54. Renewal of horses.
55. Shoeing expenses (includes shoeing horses, maintenance of shoeing tools, and any other expenses of shops where horses are shod).
56. Repairs of harness.
57. ,, and renewals of blankets and robes.
58. Veterinary services.
59. ,, supplies and expenses.

Maintenance of Electric Equipment.

60. Maintenance of steam equipment of power stations.
61. ,, electric ,, ,, ,, ,,
62. ,, feeder lines.
63. ,, line and car equipment (will be subdivided as follows, and all charges must be made to one or other of the subdivisions):

63 A. Maintenance of poles.
63 B. ,, overhead lines.
63 C. ,, track wiring.
63 D. Electric lamps for cars. (Supply of lamps only.)
63 E. Maintenance of motor armatures.
63 F. ,, ,, gearing.
63 G. ,, motors, miscellaneous.

This account will include all repairs of motors, trolleys, wiring and electrical equipment of cars, except as specified in the four preceding accounts.

Transportation Expenses.

Superintendence and General Expenses of Transportation.

64. Superintendent of routes and clerks.
65. Division superintendents and clerks.
66. Chief conductors, inspectors, starters, and aids.
67. Station receivers and register inspectors.
68. Miscellaneous transportation expenses.

Injuries and Damages.

69. Damages to persons by horse cars.
70. „ „ electric cars.
71. „ property by horse cars.
72. „ „ electric cars.
73. „ and gratuities to employés.
74. Miscellaneous damages.

Road and Snow Expenses.

75. Labour, watching holes, and flagging cars.
76. „ track cleaners and switchmen.
77. Sanding and watering track (labour, sand, sand-boxes, &c.).
78. Oil for track.
79. Labour, removing ice and snow.
80. Teaming ice and snow. (Hired teams.)
81. Salt for tracks.
82. Tools and miscellaneous snow expense.

Station and Stable Service.

83. Stable superintendence (wages, stable foremen, clerks, stable and hay inspectors and clerks).
84. Superintendence electric stations (foremen and clerks).
85. Ostlers.
86. Feeders.
87. Floormen.
88. Shifters.
89. Teamsters and expressmen.
90. Harness cleaners.
91. Lamp cleaners.
92. Car cleaners.
93. Firemen (for heating stations).
94. Watchmen.
95. Miscellaneous stable labour.

Provender.

96. Hay.
97. Grain.
98. Salt and miscellaneous provender.

Stable and Station Supplies and Expense.

99. Fuel, lights, aud electric lamps for stations, stables and cars.
100. Furniture, fixtures, tools, and equipment for stations and stables.
101. Water for stations and stables.
102. Bedding for horses.
103. Miscellaneous supplies and expenses of stations and stables.

Car Service and Expense.

104. Conductors, horse cars.
105. „ electric cars.
106. Drivers, horse cars.

107. Motormen.
108. Drivers, tow cars.
109. Tow horse service and expense.
110. Lubricating oil, waste, and misellaneous car supplies.

Electric Motive Power.

111. Steam and electric superintendence and general expense.
112. Labour for power account.
113. Fuel for power account.
114. Miscellaneous supplies and expenses for power.

Use of Horses.

115. Use of horses. (Credit account).

Schedule of Open Construction and Equipment Accounts.

Expenditure for new construction and equipment, during the year, to be charged as follows, but only upon the auditor's approval.

New Construction.

Construction of Tracks.

Grading and paving.
Track, rails, timber, &c.
Engineering and general expenses.

Construction of Electric Roads.

Line Construction.

Wiring tracks.
Poles and setting.
Overhead lines.
Feeder lines (overhead).
Feeder lines (underground).
Line construction tools.

Power Stations.

Power houses—specifying each.
Equipment of power stations—specifying each.

Electric Car Houses and Shops.

Electric car houses and shops.
Equipment of electric car houses and shops.

Engineering and General Expense.

Electric engineering and general expenses electric construction.

New Equipment.

New electric cars (includes cost of cars, motors, and other equipment).
New passenger cars—other than electric cars.
New electric snow equipment (includes all motors and electric equipment of same).
New snow ploughs and working cars.
New vehicles—carriages, waggons, and vehicles not running on tracks.
New harness and blankets.
New machinery, tools, and miscellaneous equipment.

The above schedules include those accounts which will be mainly required for charges by the electric department, but are not intended to prevent charges by that department to the other operating expense accounts of the road in case occasion arises.

New Real Estate.

New real estate purchased.
New buildings—other than for electric purposes.

Elevated Railroad Construction.

Engineering and general expenses, elevated railroad construction.

Fixed Charges.

Interest.—Includes all payments made on account of funded or floating debt.

Rents.—Include rentals of leased lines, buildings of every description, and ground rents.

Taxes.—Assessed on property used in operating the road, on earnings, and on capital amount.

Franchise Charges.—Include payments made to the city on gross earnings in consideration of franchise.

Having discussed the method of subdivision, the next point is how to keep the accounts in as simple and effectual a manner as possible.

Two principal books of record are required, the number of minor books and forms from which these are compiled varying with the size of the enterprise and the methods preferred by the manager.

Where a company exploits various methods of traction on different lines—as, for instance, horses, cable, and electric—the best method is to divide each of the main vertical columns into three, and head them Horse, Cable, Electric, so that at a glance the expenses of each are ascertainable.

The second book necessary is the ledger, and does not differ substantially from the ordinary commercial ledger.

It is necessary to keep careful track of the several items of material and labour, so that they may unfailingly reach their proper subdivision. For this purpose it is proposed to reproduce a few of the forms found most useful in America for this purpose.

When supplies are required, the purchasing agent of the railway company sends an order, of which he keeps a carbon duplicate. With this order he sends special forms on which the invoice to the company is made out and the shipping notice containing the list and amount of goods sent, thus making it possible to separate and to always know at a glance invoices, shipping notices, &c., the various forms being different in size and colour, so as to make them easily distinguishable.

When the foreman of any department requires any supplies, he fills in a form and sends it to the purchasing agent, after it has first passed the general manager, and been approved by him.

When the goods have been ordered, the auditor or accountant sends the form to the foreman who has ordered the goods, who signs for them and returns the form to the general manager, who signs and forwards to the auditor or accountant, who verifies and finally despatches it to the cashier, who then pays the amount.

We reproduce some extremely well-thought-out forms taken from the *American Street Railway Journal.*

Form A, Table CXVIII., is a card used in the store-room. There is a separate card for each box or compartment in which material is kept; and, as will be seen, each card is good for one year. The different headings explain themselves. On the opposite side of this card (Form B) is given a record of the material taken from the compartment. The card is placed upon a file near the section where the number is located, and at night is in a safe, so that if the store-room should burn down, the company will have an accurate inventory of all supplies on hand.

Every department ought to have a time and material book, the pages of which are shown by Forms C, D, that covering material used being on one page, and the time expended under the different days of the month on the opposite page.

For every piece of work performed in any department, a shop order-form E is issued by the store-room. Each shop order is given an order number, and this order number is entered in the time and material book when the work is begun.

In the time and material record-book (Form F) all material used in any order is entered under its order number on the material side, together with its cost. All labour, and by whom performed, is also accounted for from day to day, on the other side. When the job is completed, if the order number has passed through two or three divisions of the repair-sheet, the footings of the two or three time and material records show the full expense of the repair, or the newly-made article.

In conjunction with these forms there is also a daily time-sheet, shown in Form G, which is made out by the men in the different departments. This gives the order number, a description of the work, the number of hours put in, the department in which the work is performed, and such remarks as the workman may want to make. This time-sheet is

approved by the foreman, and is signed by the man who has done the work.

The storekeeper reports each day to the superintendent all materials issued by him on the previous day, showing the name of the article, the amount, the classification, and the price. This sheet is shown in Form H.

The storekeeper, by looking at Form A, can from time to time check the use of any article and the stock in hand.

Form I shows the card attached to every piece of work in the process of construction or repair.

Forms K and L are most useful, and need no description, as they are self-explanatory.

Form M is made out by the foreman at the different barns and sent in to the master mechanic each evening, and gives the amount of work done to the cars.

On the back of this form spaces are left for the numbers of disabled cars in each car barn at the time of closing the report, and for general remarks.

TABLE CXVIII.—Electric Railway Bookkeeping.

Form A.—*Store-Room Card.*

Article No.________ Name________

Date.	On Hand last day Previous Month.	Due on Requisition.	Received on Requisition.	Received by Transfer.	Total.	Amount Consumed	Amount Transferred.	Remaining on Hand.	Amount Required.	Remarks.
January										
February ..										
March										
April										
May										
June										
July										
August										
September ..										
October										
November ..										
December ..										

Net cost________

Article No.________ Name________

FORM B.—*Store-Room Card.*

From ____________________

DATE.	RECORD OF MATERIAL USED.																															TOTAL.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
January																																
February																																
March..																																
April																																
May																																
June																																
July																																
August																																
September																																
October																																
November																																
December																																

(Front and Back.)

FORM C.—*Material Used.*

189

Line ____________________ Dept. ____________________

Car No. ____________________ Order No. ____________________ Date ____________________ 189

Date and Order No.	Quantity.	Article.	Price.	Total.	Date and Order No.	Quantity.	Article.	Price.	Total.

FORM D.—*Time Expended.*

Line ____________________ Dept. ____________________

Car No. ____________________ Order No. ____________________ Date ____________________ 189

NAME.	Date Completed.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total Hours.	Rate per Hour.	TOTAL.

Form E.—*Buffalo Railway Company.*

Shop Order.

Date________________189

Foreman________________Dept.

Please make or repair following articles, *use order No.*________ for all *work* and *material* put in repairing or making same.

Articles________________________________

Form F.—*Time and Material Record Book.*

Workman.	No. Hours.	Cost.	Quantity.	Material.	Cost.	Remarks.
Total ..						

Received________________189

Commenced work____________189

Finished________________189

Repaired or new____________work

Entered,

____
Storekeeper.

____
Foreman.

Form G.—*Buffalo Railway Company.*

Daily Time Sheet.

Date____________189

Description of Work.	Order No.	Number Hours.	Department.	Remarks.
Total				

Rate per day____________

Name ____________

Approved,

____
Foreman.

Form H.—*Buffalo Railway Company.—Store Room.*

Daily Distribution Report of Material.

Folio No.____________

Date____________189

No. of Pieces.	Articles.	Classification.	Fig.	Letter.	Price.	Amount.

Form I.—*General Jobbing Tag.*

________________ Department.

Department Foreman: You will do the work described below and ____________ use Order No. ______

____

Master Mechanic.

Description of work to be done.

1. Received ____________ 189
2. Commenced work ____________ 189
3. Finished ____________ 189
4. Repaired or new ____________ work.

____

Foreman.

Printed on Back of Jobbing Tag.—The work described to be done on this tag must be followed to the letter. If the job requires more work than is outlined, the department foreman must confer with the master mechanic and receive orders before doing any other work on job.

Department foreman will securely attach this tag to any work to be repaired, or to any new work as it progresses. He will fill out line No. 1 as soon as he receives tag. Line No. 2 as soon as work is commenced. Lines Nos. 3 and 4 as soon as work is finished. Then sign and return to storekeeper.

____

Master Mechanic.

Approved:

____

Superintendent.

Form K.—*Mileage of Cars.*

No.	January	Feb.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.	Total.	Remarks.

Form L.—*Wheel Record.*

Date Applied.	New or S. Hand.	Car No.	Line.	Wheel No.	Axle No.	Cause of Removal.	Maker.	Dates.	Maker's No.	Miles Run.

Form M.—*Buffalo Railway Company—Daily Report.*

Work done at Barn ____________ Motor Dept. ____________ 189

Car No.	Cause and Nature of Trouble.	Material Used.	Labour Hours.	Time in.	Time Ready for Service.

CHAPTER XXXII.

THE MANAGEMENT OF ELECTRIC LINES.

WHEN accidents happen, it is of the greatest importance that the motor-men or conductors be provided with proper forms wherein all the details of such an accident can be at once filled in and attested by proper witnesses. If not, the tramway company is liable to be sued for damage which was never done. The filling in of such a form, signed by witnesses, is also a proper check on the conduct of the company's employés.

When cars come into the shed at night after their day's work, motor-men should hand in to the foreman of the car-barn blanks mentioning any particular points which require the attention of cleaners or repair-men. It is obvious that on the repair and inspection department depends the percentage of rolling stock available in the car-barns, and this department is second in importance to none. Table CXIX. shows a very useful type of motor-man's report, which, like the other forms, are copies of those in use on some of the large electric lines in America. It is a good plan to have inspectors placed at such points of the road that every car in the service must pass them a certain number of times each day. Table CXX. is an inspector's report; the inspector keeps a special sheet for each car. The motor-man's report is filled in every day by the motor-man and relief motor-man, each car having one report per day. Each motor-man has a column to himself, at the bottom of which he signs before turning it over to his successor. The inspector's and motor-man's reports are handed in at night at the car-barn, and the repair-men and cleaners work accordingly. These reports serve to check each other. A further check on the care with which the above two reports are made out is furnished by the time-sheets of the night repair-men and cleaners. These have to turn in their sheets filled up in such a way as to show exactly what they have been working on, and how long each particular piece of work has taken them.

Table CXXI. shows a form which should be sent in to the head office monthly, and which serves to show the condition of the various motor cars in each car-barn. It is made out by the chief clerk in the car-barn.

Table CXXII. should be kept for each car, and sent in to the office at the end of every month. By this means the number of miles per motor car and per trail car can be recorded, track kept of depreciation of each car, and the treatment it has received. This blank can be filled from the conductor's reports. These latter should cover the number of passengers carried on each trip, the number of trips made, and the route and the times of arrival and departure. There are many excellent forms existing for this purpose well known to tramway men, and these do not differ materially whatever the motive power employed.

TABLE CXIX.—FORM OF MOTOR-MAN'S REPORT

Car No.______ ______189

Took car at	M	M	M	M
Brakes				
Controllers				
Lamps, oil				
„ electric				
Light connections				
Gates and guards ..				
Motor No. 1				
„ No. 2				
Gears				
Pinions				
Oil cups				
Fuse				
Brushes				
Trolley				
Arrester				
Hot box				
Curtains				
Line trouble				
Track trouble				
Trailer No.				
Light connections .. .				
Lamps, oil				
„ electric..				
Guards				
Curtains				
Left Car at	M	M	M	M

NOTE.—Mark "O. K." or "B. O.," and fill in time of taking and leaving car, and sign in same column. Explain on back of report if necessary. Each motor-man to fill out and hand to his relief; last man to put in box at barn.

TABLE CXX.—FORM OF INSPECTOR'S REPORT.

Car No.______ ______189 .

Time.	Motor-man.	Condition.
m		

______, Inspector.

TABLE CXXI.—Monthly Report of Condition of Cars.

Report of condition of motor cars on ____________ Division.

____________ 189 .

____________ Div. Clerk.

Car Number.	In Shops.		Out Shops.		Remarks.
	Date.	Time.	Date.	Time.	

TABLE CXXII.—Monthly Mileage Return.

Daily account of trips run and monthly report of revenue mileage of .. .. { S ________ D ________

Motor electric car No. ________ and cars towed by it for the month of ________ 189

Date.	Route.	Revenue Motor Trips.	Revenue Towed Trips.
1			
Total			

Summary of Mileage.

Motor trips on Route No. ______ @ .	Towed trips on Route No. ______ @ .
Total motor mileage ________	Total towed mileage ________

The forms already given are not for the accountants, or to facilitate audit, but to show the manager at a glance when anything is going wrong, and point out where savings may be effected.

Table CXXIII. is taken from the annual report of a very large and well-managed street railway, and is a model as to how statistics should be placed before the board of directors by the manager.

We now come to another series of records; these are the power-house records—daily, weekly, monthly, and annual. They are of the greatest engineering interest, and upon their being properly kept largely depends the success of a station, and the effective comparison of various types of plant, apparatus, and systems.

Records can, of course, be pushed to extremes, and the engineer should not be called upon to do simply clerical work. He should fill in blanks

which furnish a complete history of the power station, and from them the office can compute costs of operating each particular part.

TABLE CXXIII.—ANNUAL SUMMARY OF STATISTICS.

Items.	1894.	1895.
Earnings.		
Gross earnings, from passengers		
,, per mile of street		
,, ,, track		
,, per car mile		
,, per capita served		
,, per passenger carried		
Other income, per car-mile		
Operation.		
Car-miles run		
Passengers carried		
,, ,, per car-mile		
Population served		
Area served, square miles		
Operating expenses.		
General expenses per car-mile		
Transportation ,, ,,		
Maintenance of way, per car-mile		
,, equipment, per car-mile		
Total operating expenses, per car-mile		
,, ,, ,, per passenger carried		
Fixed charges per car-mile		
,, per passenger carried		
Equipment.		
Capital stock per mile track		
Funded debt ,,		
Other debt ,,		
Cars in service		
,, per mile track		
Repairs, road-bed per mile road		
,, equipment ,,		
Road and Equipment.		
Road-bed:		
Miles of single track		
,, double ,,		
Total mileage of track		
,, ,, street		
Overhead construction, miles		
Power station:		
Horse-power, engines		
,, dynamos		
Barns and stables:		
Number of horses		

Items.	1894.	1895.
Road and Equipment.—continued.		
Rolling Stock:		
Number of closed cars		
,, open ,,		
,, motor ,,		
,, snow sweepers, &c.		
Construction and Equipment.		
Road-Bed:		
New lines of double track		
,, ,, single ,,		
,, second track		
,, track wiring		
Overhead electric construction		
Power Station:		
Additions to steam plants		
,, electric plant		
Barns and Stables:		
Increase of horses		
,, equipment		
Rolling Stock:		
Additions to closed car bodies		
,, open ,, ,,		
,, trucks		
,, motors		
Repair Shops:		
Additions to plant		
Totals		
Recapitulation.		
Gross earnings		
Operating expenses		
Earnings over operating expenses		
Fixed charges		
Net earnings		
Construction account		
Surplus applicable to dividends		
Dividends paid		
Surplus account		
Percentages.		
Percentage operating expenses to gross earn'gs		
,, fixed charges to gross earnings		
,, net earnings ,, ,,		
,, dividends on stock		
,, interest on bonds		

In each engine-room, boiler room, repair-shop, car-shed, &c., a clock should be fixed, and each department should have a slate hung up, on which any notes or memoranda can be entered at the moment of their occurrence, and from which they can be transferred later to proper blanks, which are handed in every day to the chief engineer. From the fireman's log all information concerning coal, water consumption, &c., should be obtainable; this form should be filled in at the end of each watch by the chief stoker.

Table CXXIV. is a blank, filled in by the chief engine-driver and handed in at the end of his watch. Table CXXV. is filled in by the switchboard attendant, readings being taken, say, every hour on the various instruments connected with the generators and feeders, a difference of, say,

five or ten minutes being made between the readings taken on consecutive generators and feeders, so as to give the switchboard attendant time to enter on his sheet these various readings.

TABLE CXXIV.—Engine-Drivers' Report.

Time.	Engine No. 1.			Time.	Engine No. 2.			Time.	Engine No. 3.			Cylinder Oil Used.	Oil for Bearings.	Remarks.
	On.	Off.	Run.		On.	Off.	Run.		On.	Off.	Run.			

Signature of Chief Engine-Driver________________

TABLE CXXV.—Electrician's Daily Report—Power House.

Generator No. 1.								Generator No. 2.							
Time.	On.	Off.	Hours Run.	Amps.	Watt-meter Reading.	Dif-ference.	Kilo-watts.	Time.	On.	Off.	Hours Run.	Amps.	Watt-meter Reading.	Dif-ference.	Kilo-watts.

Main Ammeters.	Main Wattmeters.			Main Volts.	Feeder No. 1.					Feeder No. 2.					Circuit Breakers.		Remarks.
	Read-ing.	Dif-ference.	Kilo-watts.		Time.	Watt-meter Reading	Dif-ference.	Kilo-watts.	Amps.	Time.	Watt-meter Reading	Dif-ference.	Kilo-watts.	Amps.	Time.	No.	

From the preceding forms the chief engineer can make up his daily reports to the general manager.

The form on which this report is made contains columns recording the going out of circuit-breakers, the time of occurrence, and the length of time the circuit was cut out. From these records the line superintendent can generally locate the trouble, and determine its cause. Under the heading "Remarks," such items as cleaning boilers, purifiers, economisers, should be entered, and attention should be called to any particular point which in the engineer's estimation should be changed, or to any addition which would be advantageous to try. With such a report, and with the daily charts of a main recording volt and ampere meter before him, the manager can at once ascertain whether his plant is working at its highest efficiency or not, and see where economy can be effected.

A very carefully worked out power-station record is given in Table CXXVI., reproduced from the *Street Railway Journal.*

TABLE CXXVI.—POWER STATION RECORD OF ELECTRIC STREET RAILWAY COMPANY FOR THE YEAR ENDING SEPTEMBER 30, 1895.

PERIOD.—1894-5.	Coal Consumed, Tons 2240 lb.	Car-Miles Run.			Coal Consumed per Mile.		Passengers Carried.		Ton Miles (2000 Lb. per Ton.)				Coal Consumed.	
		Motor.	Trailers.	Total.	Motor.	Total.	Total.	Per Car-Mile.	Passengers. 140 Lb Each.	Motors. 6.5 Tons.	Trailers. 2.5 Tons.	Total.	Per Ton-Mile.	Per Passenger per Mile.
					lb.	lb.							lb.	lb.
October	1,512.8	437,657	54,949	492,606	7.7	6.8	2,063,818	4.2	144,467	2,844,770	147,372	3,136,609	1.07	1.6
November	1,426.6	402,822 *a*	34,096	436,918	7.9	7.3	1,868,646	4.3	130,805	2,615,943	85,240	2,831,988	1.13	1.7
December	1,434.8	389,197 *b*	20,629	409,826	8.2	7 8	1,792,215	4.4	125,450	2,529,780	51,572	2,706,802	1.18	1.8
January	1,419.7	386,506 *c*	15,818	492,324	8.2	7.8	1,747,240	4.4	122,306	2,512,289	39,545	2,674,140	1.18	1.8
February	1,350.7	369,008 *d*	15,975	384,983	8.2	7.8	1,588,920	4.2	111,224	2,398,552	39,937	2,549,713	1.18	1.9
March .. .	1,502.0	433,354 *e*	23,730	457,084	7.7	7.3	1,865,409	4.1	130,578	2,816,801	59,325	3,006,704	.1.11	1.8
April (1st to 17th)	857.8	254,940	11,228	266,168	7.5	7.2	1,076,776	4.05	75,374	1,657,110	28,070	1,760,554	1.09	1.8
„ (18th to 30th)	940.3 *f*	207,995	19,283	227.278	10.1	9.3	920,517	4.05	64,436	1,350,967	48,207	1,463,610	1.44	2.28
May	1,647.6	538,355	90,720	629,075	6.8	5.8	2,375,320	3.7	166,272	3,499,307	226,800	3.892,379	0.94	1.55
June	1,688.6 *g*	539,312	117,761	656,573	7.0	5.7	2,612,940	4.0	182,905	3,505,528	293,152	3,981,585	0.95	1.44
July .. .	1,858.8 *h*	575,555	117,954	693,509	7.2	6.0	2,582,259	3.7	180,758	3,741,107	294,885	4,216,750	0.98	1.57
August	1,794.4 *i*	572,905	72,886	645,791	7.0	6 2	2,570,165	4.0	179,911	3,723,882	182,215	4,086,008	0.98	1.56
September ..	1,737.5 *j*	569,975	59,528	629,503	6.8	6.1	2,793,533	4.4	195,547	3,704 837	148,820	4,049,204	0.96	1.39
Twelve months	19,171.6	5,677,581	654,557	6,421,638	7.6	6.9	25,857,758	4.1	1,810,033	36,900,873	1,645,140	40,356,046	1.08	1.68

PERIOD.—1894-5.	Total Engine Hours.	Watt-Hours and Electrical Horse-Power Hours.					Coal per E.H.P.	Motor Cars.											
		Total Output Horse-Power Hours.	Per Motor Mile. Watt-Hours.	Per Pound of Coal. Watt-Hours.	Per Engine Hour. Horse-Power.	Per Ton-Mile. Watt-Hours.		Total on Road.	Average per Diem.	Car-Hours.	Speed per Mile.	Min. per Mile.	Watt-Hours per Car-Hour.	Watt-Hours per Mile.	Watts per Mile.	Ton-Miles per Car-Mile.	Watts per Ton-Mile.	Effort per Ton per Mile. Foot-Pounds.	Average Pull per Ton.
							lb.												lb.
October .. .	2,454	1,233,998	2103	271	502.8	293	2.74	3 516	113.42	64,758	6.75	8.88	14,210	2103	18.675	7.16	2608	115,274	21.6
November	2,134	1,203,318	2228	281	564	317	2.65	3,219	107.30	57,758	7.0	8.57	15,542	2228	19,094	7.03	2716	120,047	22.7
December	1,979	1,179 847	2275	274	596	325	2.72	3,048	100.60	53,744	7.24	8 27	16,377	2261	18,698	6.95	2690	118,898	22.5
January	,950	1,134,686	2190	266	582	316	2.80	2,988	96.39	51,778	7.4	8.10	16,348	2190	17,739	6.91	2567	113,461	21.5
February	1,756	1,044,387	2111	256	594	305	2 90	2,825	104.63	49,583	7.4	8.10	15,713	2111	17,099	6 91	2473	109,306	20.7
March	1,926	1,203,387	2071	266	624	298	2.79	3,299	106.42	56,710	7.64	7.85	15,830	2071	16,257	6.94	2343	103,561	19.6
April (1st to 17th)	1,046	663,654	1942	257	634	281	2.89	1,969	115.82	33,127	7.69	7.8	14,945	1942	15,148	6.90	2195	97,019	18 3
„ (18th to 30th)	833	535,958	1926	190	643	273	3.93	1,576	121.23	27,165	7.66	7.83	14,748	1926	15,080	7.03	2145	94,809	18.0
May	2,127	1,354,978	1877	274	637	259	2.72	3,982	128.45	70,912	7.59	7.89	14,254	1877	14,810	7.23	2048	90,522	17.1
June	2,198	1,369,049	1893	270	623	256	2.76	4,049	134.97	72,140	7.47	8.03	14,157	1893	15,200	7.38	2057	90,909	17.2
July	2,295	1,474,124	1910	264	642	260	2.82	4,458	143.81	77,343	7.44	8.06	14,218	1910	15,394	7.33	2100	92,820	17.6
August	2,268	1,450,700	1889	269	639	265	2.77	4,468	144.13	76,946	7.44	8.06	14,065	1889	15,225	7.13	2135	94,377	17.8
September ..	2,217	1,457,168	1907	279	657	268	2.67	4,425	147.5	76,873	7.41	8.10	14,141	1907	15,446	7.14	2170	95,949	18.1
Twelve months	25,183	15,305,254	2032	266	608	286	2.81	43,822	120.51	61,557	7.37	8.14	14,977	2031	16,562	7.09	2340	103,420	19.5

a Including sweeper and snow-car mileage, 841.
b „ „ „ „ 2306.
c „ „ „ „ 5973.
d „ „ „ „ 11,938.
e „ „ „ „ 1971.

f Engines running non-condensing from 18th to 30th.
g Coal, 1089 tons screenings, 599 tons run of mine.
h „ 1784 „ 75 „ „
i „ 1771 „ 24 „ „
j „ 1629 „ 108 „ „

The purpose of such records is to establish the amount of power and coal used per passenger carried, per motor and trailer car-mile and per ton-mile, and to ascertain the causes which create an increase or decrease in these quantities. In the present instance it is seen that the power used was highest in November, and that it gradually decreased to May. Part

of this decrease may be attributed to better weather, but the greater part was due to the introduction of series-parallel controllers on the cars.

An interesting column is that headed "Average Pull per Ton." Here, instead of starting with a drawbar pull as measured with dynamometer, and working up to the horse-power required at the station, the process has been reversed, and from the total power-station output the drawbar pull has been calculated. The column giving pounds of coal per watt hour and electrical horse-power hour is of great value, as by it a manager can determine the comparative merits of different kinds of coal and of various systems of operating the station.

CHAPTER XXXIII.

ORGANISATION, DISCIPLINE, AND RULES.

WITH the introduction of an improved mechanical system of traction on tramways, the question of rules and discipline for the employés of the station and on the line becomes of the utmost importance. In the transportation department financial success, to a very large extent, depends on the perfection of the rules and the accuracy with which they are carried out by motor-men and conductors.

The best code of rules, however, is not sufficient to secure success. A complete system of supervision must be in existence, by which it is possible to ascertain that the rules are attended to and carried out in a proper way. Experience proves that incentives are preferable to penalties.

Employés should always understand that punishment is an inevitable consequence of disregarding fixed rules, and that the only way of rising in the service is by faithful, thorough work and attendance to rules; that no favouritism is ever shown, and that before the highest rank can be attained all intermediate steps must be mounted.

The employés of a tramway company are its representatives in the eyes of the public, and as they are careful, civil, and attentive, or the reverse, the public will view the company with favour or disfavour. The better the class of men employed, the easier it is to enforce good rules, and to be certain of their honesty and faithfulness towards their company.

It is evidently impossible that any stereotyped set of rules will fit every case. The object of this chapter is to indicate the principles which should be kept in mind in getting them up.

Verbal rules and orders should be avoided entirely; regulations, orders, instructions, and notices should be written or printed, and posted where all employés whom they concern must see them.

The care with which such forms are prepared by the West End Street Railway show the pains taken by them to secure an efficient staff. They have been chiefly drawn up by its general manager, Mr. Sergeant.

A preliminary form has to be filled in by every applicant. After this has been read and approved by the manager, motor-men and conductors are obliged to pass examinations and fill in further forms. The examination passed satisfactorily, a bond for 300 dols. must be given to the company. The applicants are then put on lists of spare conductors and drivers, and fill vacancies as they occur.

To obviate strikes, it is always well to have a written agreement between the company and its staff of conductors and drivers.

To the rules governing the handling of the apparatus a set of rules, which, of course, vary in each place as regards traffic arrangements, should be added.

Rules and regulations should always be published as a whole, so that all the employés are aware of the rules made for the whole staff. Separately printing rules for various parts of the staff has not been found advisable.

The regulations should be printed on strong paper, and bound in a semi-flexible, strong, and waterproof binding. A pocket should be furnished inside the cover, where the employés can put any special orders which may have been issued. At the end of each section of the rules there should be a few blank leaves where the employés can add any new rules which may have been from time to time made. A thorough and copious index is an essential part of such a work. Every copy should be numbered, and the name of the employé to whom the book is given should be registered.

A notice should precede the rules stating that they are issued by the company, and to what departments they apply. This notice should also clearly state the limit of authority and power of the various foremen, heads of departments, inspectors, &c., so as to prevent any conflict arising. As such a book of rules represents the law as regards the employés, it should be specially stated that the company have a right to punish for violation of such rules, and that the men will be held responsible for any loss or damage caused by such violations. It should also be stated that by the mere fact of a person entering the company's employ he accepts the rules and conditions laid down. In order to prevent any dispute, many large companies now make it a general practice to have their men sign a paper wherein they state that they have received a copy of rules and regulations, carefully read them, and that they agree to accept employment under the conditions therein set forth. In nearly all the States of America there are special laws regarding railways, and in several States there are specially governed bodies, known under the name of Railroad Commissioners, who consider

and make special laws for railway companies. In most instances certain rules and conditions are laid down in the franchises granted to railway companies. Such rules ought always to be incorporated in the company's book.

Organisation.—It is of great importance that motor-men should possess good eyesight and perfect hearing, this being absolutely necessary where mechanical traction and high speeds are concerned, and most large American companies now require a medical certificate as to the eyesight and hearing before engaging a motor-man.

A specific penalty should never be fixed for the violation of a rule, this question being left entirely to the manager, the disposition and standing of each individual offender having to be carefully studied. There are two distinct ideas as regards the best way of training motor-men, either, if properly carried out, giving exceedingly good results. As an example of the mode adopted by two very large companies, both most successfully operated, we will quote the Chicago City and the West Chicago City Railway companies.

The motor-men in the employ of the Chicago City Railway Company undergo a training in a school conducted by the foremen and assistant-superintendents in a room provided by the company in one of the car-houses. A part of the class-room equipment consists of a dissected car in which all the parts are accessible. Instruction is given in regard to the car, adjustment of motors, wiring, and switches, and the arrangement of all parts. The intention is that the motor-men should be able to make any necessary small repairs to the cars. They are also taught the effect of the current on the motors, and how to handle the controller, brakes, and switches, as well as their duties under the rules. The explanation of short circuits and brakes, and the result upon machinery and line, are carefully explained. The lessons are given at nine and one o'clock two days in the week, so that the employés can have the advantage of the school when they are off duty.

In contrast with the above, the instruction given to the motor-men of the West Chicago Company is confined to their platform duties. They are taught how to handle the controller, brake handle, and switches, and to adjust the fuses, but further than this know nothing about the equipment. In the opinion of the superintendent there is little about a motor to which access can be had while the car is on the road, and if the motor-man undertakes to adjust mechanical or electrical parts, he is apt to do more

harm than good, and to block the line and derange traffic. If anything goes wrong with the mechanism, the car is to be pushed in by the succeeding car, and turned over to experts for repairs and adjustments. Special repair men are stationed at certain points of the line, and light repairs can be made there, if necessary. The first system is possibly advisable when dealing with a line where electricity has been long in use, and the men already have a fair idea of the various parts which they have to handle; it requires an extremely high class of employés. In the case of a horse-road introducing cars, the first system would be absolutely fatal to begin with, as it is impossible that drivers should suddenly become mechanics. On some lines conductors and motor-men periodically exchange duties, and are also required at times to spend some days in the repair shops and car-shed. They thus acquire a fair knowledge of the machinery which they handle.

In America the ticket system used here is not adopted. Automatic registers are put in the cars, and as each passenger pays his fare a bell is rung and the passenger is recorded. Uniform fares are nearly always charged, 5 cents. ($2\frac{1}{2}$d.) being the rule. On many roads transfer tickets are given over connecting lines of the same system. Such tickets have the month, the day of the month, and the time of day printed on them, as well as the various sections at which they are available. The conductor punches out the month, day, time, and route to be taken by the passenger, retaining a duplicate which is turned in with his receipts at night. For these duplicates he receives new transfer tickets. The receiving conductor registers the transfer ticket as if it were a fare. Such a system requires a very elaborate system of checking, and even then frauds are possible. Every large company in America has its secret service, or detective department, not only for the detection of fraud, but to enforce discipline. This is regarded as one of the necessary evils of street railroading. Upon its being properly conducted may depend financial success. The practice of one large and admirably managed company is as follows:

The department is supervised by a chief inspector. Two classes of inspectors, open and secret, are employed. The first class is composed of men in the regular employ of the company, known to the other employés, whose duty it is to inspect, instruct, advise, and report in person to the chief inspector or superintendent.

The second class is composed of men and women who are employed for a limited time, not known by the other employés, and who ride upon the

cars as passengers, and note and report the manner in which conductors, drivers, or other employés perform their duties. This inspection not only relates to the registering of fares, but to the conduct of the employés while on or off duty, and the manner in which they treat their patrons, the general public, and fellow-employés. Their ranks are generally recruited from a class of wandering professionals, or they are furnished by reliable detective offices. Each is given a number by which he or she is to be known, and supplied with the necessary blanks, stationery, &c., and a book of rules.

Every day each detective hands in a report, worked out on a special form in which spaces are left for the number of the car route, the number of the conductor's or motor-man's badge, the place where the car was entered by the detective, the time, the place of leaving the car and the time—and then follow the number of fares not registered, but which were taken, the number of fares missed or passed by, the total number of passengers at that particular time, and after this is a blank column in which the names corresponding to the badges are filled in at the head office. A column of remarks is attached to the form, in which such notes as the conduct of the motormen and conductors, the state of their uniform, their efficiency, &c., whether good or bad, are entered. From this report the book of the head of the detective service is filled in. Whenever an employé has been found to be lax in the performance of his duties, he is called before the chief inspector and asked for an explanation. If his explanation is satisfactory, no notice is taken; should it be otherwise, a mark is put against his name, and he is warned. No notice is taken of any offence if the same is only reported by one detective, and as the detectives do not know each other, it is impossible for any collusion to exist. After a conductor has been several times caught in collecting fares for his own benefit, he is discharged, but rarely if ever prosecuted. A road of the size of the West End of Boston would have about forty detectives constantly at work, none of whom know each other. These never come to the head office, but they are met on the road, and each detective has his particular route mapped out for one week in advance, so that for eight or ten days he does not travel on the same car again. Should any special work be required, the chief knows where to find detectives at given times of the day, and sends them their special work.

Special regulations are in existence for wreckage work and snow clearing. In large companies there is a corps of men employed as firemen.

The moment a fire breaks out anywhere, the fire office of the tramway company is informed at once, and a special man sent out to attend the fire, and to cut out or entirely remove, if necessary, any part of the overhead line work which may interfere with the firemen's proceedings. Where a fire hose has to cross the tracks, special apparatus is provided to prevent it being run over by passing cars. The removal of snow especially on large lines, is of the greatest importance in American cities. Very carefully thought-out plans for this work are in use. The Boston line has some 200 miles of streets to keep open, and during the very worst winter the rails are never lost, and the cars have never been blocked. This company possesses over 100 electric snow-ploughs, 80 horse snow-ploughs, and some 400 sleighs for conveying away the snow. According to Mr. Sergeant, the manager of the line, the essentials for keeping a road open are as follows:

1. Sufficient equipment, kept in perfect repair, at all times.

2. Plenty of power at the station for the increased demands caused by the electric ploughs. To secure this, all superintendents are instructed to reduce their cars as the ploughs go out, and a large auxiliary power plant, not required in summer, is kept for winter use.

3. A system of operation whereby the entire work to be done upon the road is laid out in detail in readiness for any sudden storm. Proper compliance with this system is insured by the constant supervision of experienced men.

The West End road is divided into nine sections, of which one, comprising the heart of the city, has no car-houses and runs no cars. All the other divisions run cars and ploughs over specified routes, and, when called for by telephone, into the central division. On the first fall of snow, men, who have been previously assigned to their several stations, begin work on each important piece of special track work with push brooms, shovels, &c., and keep the frogs, points, and curves constantly cleaned. As soon as the snow so removed begins to accumulate, snow sleds for each place begin hauling it away, and so long as the storm continues this work goes on, the men and horses being regularly relieved and fed, if necessary. A wagon in each division makes the rounds, and salts the curves, frogs and points, and heavy grades.

The system is so large that the snow conditions may vary greatly between the heart of the city and the suburbs. For this reason a night inspector is maintained throughout the winter in the central division,

whose special duty it is to order out by telephone the ploughs and men at any hour of the night when the snow begins to fall. It has been found very essential to follow promptly with a leveller the snow ploughs on electric lines. In very heavy storms ploughs should be run at intervals of not longer than fifteen minutes; on ordinary light snowfalls longer intervals will suffice. In the heart of the city much use is made of a "wheel" plough. This is similar to a horse plough, with share and wings, but with wagon wheels gauged to fit the track, and having sharp tyres and having no flanges. With this machine the track can first be ploughed, and then, leaving the rails, the snow can be levelled back with the same machine, a class of work which obviously cannot be done with electric ploughs.

Early experience with electric ploughs were unsatisfactory. Experience has demonstrated the need of great strength in all parts. The standard ploughs are made with heavy iron frames, on which is a wooden cab containing the motors (two motors of 25 horse-power each), the power being transmitted by very heavy sprocket chains. The wheels are 36 in. in diameter.

The plough is equipped with heavy iron diggers operated by the foot of the motor-man. All chains and other parts that are liable to break are duplicated, and the ploughs so equipped very rarely break down. The secret of keeping the road open is always to keep ahead of the snow, and this has been done in exposed places through drifts 6 ft. deep by the aid of shovellers through the severest storms. Some horse ploughs have been refitted as push ploughs, and arranged so that the power is applied in the centre of the plough, which is loaded down with old cast iron; and this, pushed by a double motor car, has given very satisfactory results. Many hired teams and hundreds of men are brought into requisition for this work, and to keep proper check and for the payment of the men special snow paymasters are appointed, who pay daily the casual labourers so employed, who are identified by their foreman and the surrender of a shovel and identification ticket. The hauling is also covered by tickets and reports, so that loss from fraud, or abuses on the part of contractors, is prevented. The expense of all this work is enormous; practically, the city's work of cleaning is thus done, for which neither payment nor credit is given.

The making up of proper routes and time tables is most important. The first essential is to ascertain what headway will pay on a given line. It is possible on every line to arrange time tables in such a manner as to

increase or reduce trips night and morning, as the weather happens to be good or bad. A great saving is effected by having a different set of tables for all the various holidays throughout the year. To determine with fair accuracy the service needed on such occasions, it is necessary to note very carefully the actual requirements on the various holidays as they pass.

In connection with working time tables and with general management, both ordinary and in case of an emergency, it is very desirable to have some means of direct communication with the car-starter or with the manager's office. This is most easily secured by means of telephone. Where private houses or offices of the tramway company can be secured, telephonic instruments are used, and connected by means of special wires. In the streets and on some of the lines the erection of special telephone boxes with instruments would be very expensive, as telephones, receivers, and transmitters are very susceptible to damp and easily get out of order. In such a case the simplest way is to have contact-boxes only and to use cheap portable telephonic instruments, one being carried by each car. Such instruments are now in use at Boston and in several other places. They are so small and compact that they can easily be carried in a coat pocket.

In some of the large western towns having systems branching 16 or 20 miles out into the country, where one small delay might practically disorganise the whole service, what is known as the despatch system is adopted. This consists of a telephone exchange at the main offices of the company, and telephone posts, or special electric signals, at various points of the line. As the cars pass these points they signal to the despatcher, who thus knows exactly the location of every car, and can, if required, alter headways as desired.

CHAPTER XXXIV.

EFFICIENCY, MAINTENANCE, AND DEPRECIATION.

IT is practically impossible to ascertain accurately at each instant the mechanical efficiency of an electric tramway system or its component parts. This depends upon their load, speed, and many other factors, which are constantly varying. The only figure which can approximately be obtained is the average efficiency, or, in other words, the ratio of the actual horse-power exerted on the wheels of the car, to the indicated horse-power at the steam engine. In discussing this question, however, we must not lose sight of the fact that, in many instances, the mechanical efficiency is not the most important point to be considered, the main desideratum being to work most economically with the least depreciation and great flexibility.

The electric motor is no prime mover. It only serves to transform the electrical energy which it receives, into motion. The initial power, from either fuel or water, has to pass through several different transformations, and naturally sustains losses. The various points of loss may be tabulated as follows:

Power-House.

Boilers or turbines. Steam-engines or turbines.
Dynamos.

Line.

Feeders.
Overhead line.
Controlling devices.
Motors.
Gearing.
Loss in friction of truck bearings.
Return circuit.

In Table CXXVII. the approximate efficiencies attained in the various parts are shown. We may conclude that in a fairly large plant a total efficiency of from 50 to 65 per cent. may be obtained, if the greatest care in the design and operation of the line is taken.

TABLE CXXVII.—GIVING APPROXIMATE EFFICIENCIES OF THE VARIOUS PARTS OF AN ELECTRIC SYSTEM.

	Per Cent.		Per Cent.
Water wheels	30	to	75
Turbines	70	„	80
Pressure engine	75	„	85
Steam engines	70	„	95
Mechanical efficiency of dynamos	80	„	95
Overhead line and feeders	85	„	95
Motors, including gear	70	„	85
Single reduction gear	90	„	95
Accumulators in central stations	70	„	86
Rotary transformers	90	„	96
Stationary alternating-current transformers	94	„	97
Return circuit	98	„	99

Minimum efficiencies under various loads of the various parts of an equipment are generally called for in specifications and guaranteed by contractors.

In nearly every case the tests specified include the measurement of the power obtained, its cost, and the quantity of fuel required. This entails careful measurement of the quantity of water, fuel, and steam used, and the determination of their quantities as well as the various wastes which take place.

When a trial includes the boiler (the combined efficiency of boiler and engine being the final object), arrangements must be made to ascertain exactly the weights of fuel gross and net, coal and ash, the weight of water supplied as "feed;" the weights, temperatures, and pressures of dry steam, and weight of entrained water; the temperatures of furnace, flues, and chimney; of superheating steam, if it be so heated; the power of the engine gross and net; the friction of engine; the wastes by cylinder condensation; the steam pressure in boiler and steam chest; and the continually varying pressure in the working cylinder throughout the whole cycle, revolution by revolution of the engine. Each of these quantities is measured at specified intervals, and a comparison of mean values of power usefully applied, and of expenditure made to produce it, gives the measure of the economy attained.

The indicator diagrams taken furnish the means of ascertaining precisely how the pressures and volumes of the steam simultaneously vary within the engine, and give a clue to the setting and motion of the valves and afford evidence as to whether the distribution of steam is such

as will conduce to the most economical working. These diagrams also permit the engineer to compute with considerable accuracy the volumes and weights of the steam at any, and at every, point in the stroke. A comparison of the quantities so calculated with the actual measures obtained at the boiler, or before the steam enters the cylinder, gives the measure of the quantity condensed in the cylinder as the piston moves forward, and of the later re-evaporation. The cylinder wastes are thus determinable with fair accuracy. These diagrams also show the amount of back pressure, and measure the resistances in the exhaust passages and at the condenser, affording a means of criticism of the design and construction of the engine in this respect. The difference between the steam pressures in the cylinder, the steam chest and the exhaust chest, is a measure of the losses in the steam passages.

In making boiler tests, the most important point is to settle on a standard of measurement and comparison, so as to be able to compare results obtained from various plants. The Committee of the Centennial Exhibition at Philadelphia adopted the unit of power of 30 lb. of water evaporated into dry steam per hour from feed water at 100 deg. Fahr., and under a pressure of 70 lb. per square inch above the atmosphere. This would equal an evaporation of 34.488 lb. from 212 deg. The losses in friction in a steam engine vary between 5 and 15 per cent., according to size and construction. For traction purposes, engines work under peculiar conditions, their load constantly fluctuating between large limits; and practice has shown that the engine for railway work should give out an effective horse-power equal to seven-eighths of the full rated power of the dynamo. To reduce the friction and to utilise the steam to its best advantage, overloading an engine is less injurious than underloading it. The engine used should be so designed that at its average load it should be working at its most economical point of cut-off. To determine the actual value of a steam engine, a comparison of the average continuous cost with the average value of the power supplied for useful work is necessary. Such trials can only be considered satisfactory when they determine the various parts as set forth as follows:

Fuel or Heat Energy Supplied.

Useful work	Friction in engines.
Wasted work	Heat loss externally. Heat loss internally.

Although in traction plants the engines cannot usually be worked at

their full load constantly, and are therefore not run as economically as they might be, yet they generally have to work for very long hours, which is distinctly in their favour as compared with electric lighting stations.

To run engines and keep boilers warm and deliver power for 24 hours, requires approximately 3 lb. of coal per Board of Trade unit, whereas if the boilers are kept warm and run the plants for only three hours per day, about 7 lb. per unit are necessary; and to keep boilers warm and pressure up without furnishing steam, requires approximately 10 per cent. of the coal consumption required to keep the boilers hot and under pressure whilst delivering steam to the engines.

Railway generators can be designed so as to give a very nearly constant efficiency at all loads. The efficiency of a well-designed 1,000 horse-power railway generator remains from one-quarter load to full load practically constant within 3 per cent.

The most interesting tests, and possibly the most difficult to obtain, are those of the line and cars, and of the loss in power which takes place between the station switchboard and the return circuit.

The first and most important factor in such tests is the reliability of the instruments used. Owing to the rapid variations of current and voltage in railway plants, accurate dead-beat instruments must be employed.

The particular tests which are of interest are:

1. Determination of the coefficient of traction, and the influence of curves, grades, type of rail, and condition of track on same.

2. Losses in various parts of the system, so as to obtain the total efficiency of the line.

To obtain the traction coefficient, a recording dynamometer could be attached between two motor cars, one pulling the other. The possible error here would seem to be the difference in the friction losses when the motors are driven by the gears, instead of when the motors drive them; also possible losses due to magnetic friction from residual magnetism, and the absence of possible side strains on the bearings existing when motors drive the cars. These might be got over by carefully ascertaining the efficiency of each car motor at various currents and speeds for given voltages, and thus being able to deduce the torque on the wheels, or the pull at their periphery for a given output.

Some interesting results are given in Table CXXVIII., which is compiled on data given by Mr. Hering. The total pull, as measured by the dynamometer, is expressed by:

$$P = W \sin \alpha + \mu W \cos \alpha$$

or,

$$\mu = \frac{P}{W \cos \alpha} - t g \alpha$$

in which

P = dynamometer pulls in pounds.
W = weight of car in pounds.
μ = coefficient of traction.
α = angle formed by grade on horizontal.

As the angle even for heavy grades is small, we can admit that $\cos a = 1$, and, therefore,

$$\mu = \frac{P}{W} - t g a$$

or expressing $t g a$ in per cent. of grade, coefficient of traction

$$= \frac{\text{dynamometer pull in pounds}}{\text{weight of car}} - \text{per cent. of grade.}$$

From this formula, the figures given in Table CXXVIII. have been worked out.

TABLE CXXVIII.—TRACTION COEFFICIENTS.

Kind of Car.	Grade.	Speed in Miles per Hour.	Weight of Car.	Dynamometer Pull.	Equivalent on Level.	Coefficient of Track Pull per Ton on Level.	Remarks.
	p.c.		lb.	lb.	lb.	lb.	
Trailer	5.95	4.11	6,270	400	26.4	9.8	Track dry
Motor Car	5.97	7.81	16,872	1,119	112	14.95	,,
,, ...	2.53	11.10	16,872	533	106.21	14.70	,,
Motor car with gears or armature	5.97	7.23	16,135	1,036	73	9.85	,,
Motor car	5.95	8.14	16,300	1,056	85	11.75	Track wet

That the results of trailing a motor car are no criterion of the horizontal pull of the car when running under its own power, is borne out by this Table: as when the gears of a motor car were removed, the traction coefficient per ton was .85 lb., as against 14.95 under similar conditions with the gears on. Now the efficiency of the simple reduction gearing used on motor cars is well over 90 per cent. This shows that the method of applying this dynamometer test by trailing a motor car will not give very satisfactory results, although interesting figures may be obtained.

Table CXXIX. gives some of the results obtained from a series of tests carried out on the electric roads of Baltimore. The conditions under

which these were carried out resembled much more those existing on a light railway than a tramway, both as regards track and speed.

TABLE CXXIX.—RESULTS OF CAR TESTS.

Items.	Outward.	Homeward.	Round Trip.	Outward.	Homeward.	Round Trip.
Length of road tested in miles	4.99	4.99	9.98	2.073	2.073	4.146
Straight track in per cent. of total	88.5	89.3	88.8	67.1	67.1	67.1*
Level track in per cent. of total	5.2	5.2	5.2	0	0	0
Ascending grade in per cent. of total	23.0	71.8	94.8	35.7	64.3	100
Descending grade in per cent. of total	71.8	23.0	94.8	64.3	35.7	100
Total rise in feet	123.7	483.0	606.7	103.0	192.7	295-7
Weight of car loaded	14,710	14,710	14.710	14,710	14.710	14.710
Mean amperes over entire road	13.0	39.6	26.3	26.2	37.7	31.9
,, speed in miles per hour	12.6	13.7	13.2	17.8	16.9	17.3
,, amperes whilst using current	28.8	45.8	40.0	43.8	56.0	50.3
,, station voltage	514	517	515	514	514	514
,, car voltage	510	505	507	497	490	493
,, drop in volts over entire road	4	12	8	17	24	20
Board of Trade units per car mile	1.642	1.675	1.159	1.861	1.375	1.117
Mean station E.H.P.	8.9	27.5	18.2	18.2	26.0	22.1
,, car ,,	8.7	24.6	17.8	17.0	23.8	20.4
E.H.P. lost in line in per cent. of station E.H.P.	2.5	3.5	3.2	6.6	8.3	7.8

* Car mounted in both tests with two "G.E. 800" motors, each weighing 1,455 lb., and "K" controllers.

It must be noted that the road tested was not an easy one, there being numerous grades and curves.

The instruments used in these tests were a tachometer, fitted to the car axle, and graduated so that at any moment the speed in miles could be read off. A Weston ammeter was put in the main trolley circuit to measure the total current supplied to the car, and another instrument of the same type was put in series with one of the motors, thus giving the current which one motor took. A Weston voltmeter was connected with the trolley and the ground to measure the total potential at each moment on each particular part of the line. The times were taken by means of a chronometer, and were determined down to quarters of a second. Voltmeter readings were also taken simultaneously at the power station, so as to measure the full voltage on the line.

It might have been better if a second ammeter had been put in series with the second motor, as it is perfectly possible that, owing either to difference in the motors or to skidding of the wheels, for the work done by one motor to vary within very large limits from that done by the other.

A recording wattmeter was placed on the car, and read at intervals. Readings on all the above instruments were taken simultaneously at given points on the line, fixed beforehand, the time being given by an observer stationed on the front of the car. It would have been interesting if the loss of power due to starting resistance and shunt resistance had been measured. This, of course, would have entailed additional instruments and

observers, but if such results had been obtained they would have been of great value.

Very elaborate diagrams can be compiled; the speeds, amperes, volts, horse-power, and watts being plotted as ordinates, while the abscissæ represent the distance in feet traversed.

Tests of this kind should be more frequent, as by their results it would be possible to determine whether a line can be improved so as to increase its mechanical efficiency without undue expenditure. It is, of course, very interesting to try and determine the actual efficiency of an electric road, but it is extremely difficult to do so. By efficiency, we mean the average ratio of the horse-power necessarily applied to move all the cars on the line at regular speed, to the total indicated horse-power given out by the engines. This efficiency, of course, is a very varying quantity, and depends, to a very large extent, on the good or bad driving by the motorman, and on the proper proportion of the units in the station, so that the average loads are as large as the engines will stand, without slowing down when maximum loads suddenly come on.

Table CXXX. gives some very interesting results obtained with a series parallel controller and a car weighing 8 tons, hauling a trailer car weighing 8.4 tons. These tests were made by Mr. Hewett on the Ithaca Street Railway. The first trip was made with the two motors in series, and the second with the two motors in parallel. By efficiency of motors is meant their electrical efficiency. The tractive force per ton varied from 36 lb. to 40 lb.

TABLE CXXX.—Traction Tests on Ithaca Street Railway.

Items.	First Run. Round Trip.	Second Run. Round Trip.
Average speed, miles per hour	5.93	10.18
,, trolley current in amperes	18.7	35
,, ,, electromotive force	456	456
,, effective motor counter-electromotive force in volts	188	384
,, applied horse-power	11.5	21.5
,, ,, ,, per ton	.7	1.3
,, delivered horse-power	9.4	17.85
,, ,, ,, per ton	.57	1.09
,, motor efficiency, per cent.	81.5	84.0
,, effective traction in pounds	596	657
,, ,, ,, ,, per ton	36.3	40
,, dynamometer traction in pounds per ton	53.6	—

Table CXXXI gives the results obtained by Mr. E. Perrett, who experimented with a passenger car weighing 3800 lb. and with a wheel base of 5 ft. 6 in., on the Nottingham Tramways. It will be seen from comparing these two Tables that the American rails are very much more

favourable than grooved rails, these latter offering more resistance to traction. Resistance to traction depends to a certain extent upon the speed and also on the gauge. Mr. Kinnear Clark, in his work on tramways, gave the figures, Table CXXXII, as regards the increase of the traction power with the speed :

TABLE CXXXI.—Giving Resistance to Traction on Grooved Rails.

Grooves.	Line.	To Start. Per Ton.	To Keep Moving. Per Ton.
		lb.	lb.
Clear	Straight and level	50	25
Very dirty	,, ,, ...	66	50
Moderately dirty	Straight, up gradient 1 in 130	106	66
,, ,, ...	,, down gradient 1 in 130	57	34
,, ,, ...	Curve 45 ft. radius, up gradient 1 in 30	86	72
,, ,, ...	Down gradient 1 in 130	62	50
,, ,, ...	Curve 22 ft. radius, up gradient 1 in 139	132	94
,, ,, ...	Down gradient, 1 in 139	95	65

TABLE CXXXII.—Giving Traction Coefficient per Ton at Various Speeds on a Railway Track.

12 lb. per ton at a speed of 1 mile per hour.	14 lb. per ton at a speed of 15 miles an hour.
13 ,, ,, ,, 10 ,,	15½ ,, ,, ,, 20 ,,

Mr. M. Tresca made some very elaborate experiments upon tractive resistances on the Paris and Versailles tramways, where grooved rails are laid in macadam, from which he deduced a resistance of 22.4 lb. per ton. It may be concluded in preparing estimates that the resistance of cars on level, straight, and well maintained tramways is 20 lb., but that on a line of average conditions 30 lb. may be assumed. This latter figure coincides with the figures given by Messrs. Merryweather and Sons from their experience. From these data it will be possible to work out the theoretical power which on a given road would be required to drive a given car at a given speed, and from this, when the average indicated horse-power is known, to work out the probable total efficiency of the entire system at a particular moment.

Undoubtedly the question which is of most importance to a tramway or railway manager, is with which system can he, by burning a given quantity of coal, propel the greatest weight at the greatest speed with the least depreciation. But this notwithstanding, efficiency tests are most necessary and instructive in showing which part of an installation is responsible for the greatest losses, and how these can be diminished.

The efficiency of the various parts of a power plant depends to a very large extent on their sizes. Higher efficiency as a rule means a very much

heavier capital expenditure which small plants often find it worth while not to incur. But in large plants a saving of a fraction per cent. on the coal bill may mean a very large item in the total expenditure.

Table CXXXIII. is of much interest, as showing the comparative working costs in large plants; it is deduced from results obtained quite recently in three large American railway installations. From it will be seen at a glance the great advantage derived by the use of large direct coupled units. The total cost of power for such a plant is .205d per car-mile, whereas for a belted plant this quantity is about 50 per cent. higher.

TABLE CXXXIII.—AVERAGE OPERATING AND MAINTENANCE EXPENSES IN PENCE, WITH VARIOUS TYPES OF PLANTS, PER CAR-MILE.

Items.	Direct Coupled Corliss Condensing Plants. Units of over 1,000 Horse-Power.		Belted Cross-Compound Condensing High-Speed Units of over 600 Horse-Power.		Belted Tandem Compound Non-condensing High-Speed Units of over 400 Horse-Power.	
	From	To	From	To	From	To
Operation Account.						
Supplies :						
Coal ..	.0964	.1377	.1150	.1643	.1756	.2509
Water	.0078	.0112	.0099	.0142	.0139	.0199
Oil, grease, and waste ..	.0061	.0087	.0093	.0133	.0056	.0060
Boilers, engines and pumps, miscellaneous	.0011	.0016	.0034	.0049	.0043	.0062
Electrical department, supplies	.0017	.0024	.0042	.0060	.0063	.0090
Labour :						
Engineers, oilers, and wipers ..	.0325	.0446	.0683	.0976	.0440	.0629
Firemen, miscellaneous..	.0306	.0437	.0429	.0614	.0263	.0376
Electrical department, labour ..	.0176	.0252	.0346	.0495	.0339	.0484
Maintenance Account.						
Supplies :						
Buildings ..	—	—	.0002	.0003	—	—
Boilers	.0003	.0004	.0029	.0042	.0021	.0030
Engines and pumps, sundries..	.0016	.0024	.0032	.0046	.0009	.0014
Electrical department, supplies	.0006	.0008	.0001(0)	.0001(5)	.0012	.0018
Labour :						
Buildings ..	.0005	.0008	.0008	.0012	—	—
Boilers	.0029	.0042	.0088	.0126	.0011	.0016
Engines and pumps, sundries ..	.0043	.0062	.0108	.0155	.0017	.0025
Electrical department, labour..	.0010	.0014	.0003	.0005	.0011	.0016
Résumé.						
Cost of operation ..	.1938	.2751	.2876	.4112	.3099	.4409
,, repairs ..	.0112	.0162	.0271	.0390	.0081	.0119
Total cost of power ..	.2050	.2913	.3147	.4502	.3180	.4528

Table CXXXIV. gives the cost and quantities of supplies used per car-mile in the Trenton Railway last year.

Table CXXXV. gives the approximate fuel consumption and the cost per horse-power of some standard types of American engines.

The question of depreciation and maintenance, as well as the amount of power absorbed per car-mile, and the cost thereof, is most important and of great interest. Very few reliable figures have been obtainable on this point until recently.

TABLE CXXXIV.—CONSUMPTION OF MATERIAL AND COST OF WAGES IN POWER HOUSE, TRENTON RAILWAY, N.J., 1895, PER CAR-MILE.

Car mileage	1,433,919
Pounds of coal used per car-mile	5.92
Gallons of cylinder oil used per car-mile	.00055
,, engine oil ,, ,, ...	.00087
Superintendence, in pence per car-mile	.019
Engineers, ,, ,, ...	.049
Oilers, ,, ,, ...	.034
Firemen, ,, ,, ...	.037
Helpers, ,, ,, ...	.018
Repairs of engines, ,, ,, ...	.0052
,, boilers, ,, ,, ...	.0074
,, dynamos ,, ,, ...	.0031
,, piping, ,, ,, ...	.00068
,, pumps, ,, ,, ...	.0011
Fuel, in pence per car-mile	.32
Oil waste and packing, in pence per car-mile	.045
Light, in pence per car-mile	.0037
Extra labour, in pence per car-mile...	.0062

TABLE CXXXV.—APPROXIMATE CONSUMPTION AND INITIAL COST FOR AMERICAN ENGINES.

Type.	Pounds of Coal per Horse-Power-Hour.	Cost per Horse-Power. Sizes over 100 Horse-Power.
		£ s. £ s.
High-speed single	4 to 5	2 5 to 2 13
,, compound	3 ,, $3\frac{1}{2}$	2 17 ,, 3 5
,, ,, condensing	$2\frac{1}{4}$,, $2\frac{1}{2}$	
,, triple	$1\frac{3}{4}$,, 2	3 10 ,, 4 10
Corliss, single	$3\frac{1}{2}$,, 4	3 6 ,, 3 14
,, compound	—	—
,, condensing	$1\frac{3}{4}$ to 2	4 10 to 5 3
,, triple	$1\frac{1}{2}$,, $1\frac{2}{3}$	5 11 ,, 6 3

This is based on an evaporation of 9 lb. of water per pound of coal.

Table CXXXVI. may be taken as a fairly accurate representation of the percentage which ought to be allowed annually on the various parts of a power plant, so as to be within safe limits as regards maintenance and depreciation of the same.

Tables CXXXVI. to CXLI. have been compiled from a very large amount of statistics collected by the writer. They speak for themselves, and little or nothing need be added in explanation.

Table CXLII. gives the average cost per car-mile gathered from several American roads, and it will be seen that the depreciation of a bogie truck is some 30 per cent. more than on a four-wheel truck, an item which must be considered when deciding the question as to whether bogie or four-wheel trucks ought to be used.

TABLE CXXXVI.—Approximate Rates of Depreciation to be Allowed in Per Cent. of Capital Cost.

	Per Cent.		
Buildings	1	to	2
Turbines	7	,,	9
Boilers	8	,,	10
Dynamos and engines, belted plants	5	,,	10
Belts	25	,,	30
Large slow-speed steam engines	4	,,	6
,, ,, direct-driven plants	4	,,	8
Stationary transformers	5	,,	6
Accumulators in central stations	9	,,	11
Trolley line	4	,,	8
Feeder cables	3	,,	5
Lighting and current meters	8	,,	10
Cars	4	,,	6
Repair shop and test-room fittings	12	,,	15
Motors	5	,,	8
Rotary transformers	8	,,	10
Boilers and engines	6	,,	10
Spare parts	1½	,,	2
Track work	7	,,	13
Bonding	6	,,	10
On remaining capital expenditure incurred	4	,,	6

Accidents and insurance should be put down as from 0.75 per cent. to 2.25 per cent. of the gross receipts.

Taking the interest rate at 5 per cent., and supposing the entire plant must be entirely renewed at the end of 20 years, 3 per cent. on the original outlay must be set aside each year to do this.

TABLE CXXXVII.—Life of Various Portions of Electric Railway Equipment in America, Derived from Practical Experience.

Average speed of cars in miles per hour	12	to	15	
Maximum speed in miles per hour	20	,,	25	
Weight of car, in pounds	15,000	,,	18,000	lb.
Cast-iron split gears, machine-cut teeth running in oil bath	25,000	,,	35,000	miles
Cast-steel split gears, machine-cut teeth running in oil bath	50,000	,,	70,000	,,
Steel pinions, machine-cut teeth running in oil	8,700	,,	12,000	,,
Motor commutators	35,000	,,	110,000	,,
Motor armature winding on heavy roads	100,000	,,	140,000	,,
Motor armature winding on light roads	300,000	,,	400,000	,,
Motor carbon brushes		50,000		,,
Best chilled wheels	90,000	to	110,000	,,
Motor axle linings	15,000	,,	35,000	,,
,, armature bearing linings	23,000	,,	30,000	,,
Trolley wheel	4,500	,,	6,000	,,

TABLE CXXXVIII.—MAINTENANCE OF ELECTRICAL CAR EQUIPMENT IN AMERICA FOR TWELVE MONTHS.

	£	s.	d.
Trolley wheels ...	0	13	3
Commutator ...	0	0	11
Lining armature bearings...	3	16	6
,, axle bearings ...	0	11	6
Controllers ...	0	11	1
Contacts ...	0	3	5
Fingers ...	0	4	1
Total ...	6	0	9

TABLE CXXXIX.—COST OF PAINTING CARS IN AMERICA.

Items.	Labour. £ s. d.	Material. £ s. d.	Total. £ s. d.
Repainting 16 ft. closed car ..	8 7 1	3 6 7	11 13 8
,, 26 ft. open car ..	7 13 6	3 0 0	10 13 6
Touching up and varnishing 16 ft. closed car ..	2 1 7	0 12 10	2 14 5
Touching up and varnishing 26ft. open car ..	2 5 2	1 10 3	3 15 5
Recanvasing and painting car roofs 16 ft. closed cars ..	0 13 9	2 7 3	3 1 0
Recanvasing and painting car roofs 26 ft. cars ..	0 16 3	2 10 9	3 7 0

TABLE CXL.—SHOWING COST OF MAINTENANCE AND REPAIRS OF CAR AND MOTOR TRUCKS.

Name of Railway.	No. of Cars.	Repairs. Cost per Car per Annum.	Cost per Car-Mile in Pence.	Style of Equipment.
		£		
The Buffalo, Bellevue, and Lancaster (New York Railway) ..	30	30 to 52	—	——
The Niagara Falls Park and River Railway ..	25	30	0.2	W.P. 50 motors, G. E. Co.
The Salt Lake City Railroad ..	27	90	0.5	Single reduction Westinghouse motors.
The City and Suburban, Portland (Oregon) ..	35	50	—	W.P. 30 motors, double equipment, G.E. Co.
The San Francisco San Mateo Railway ..	36	82	—	S.R.G. motors, G. E. Co.
The Scranton (Philadelphia) Traction Company	50	50	0.23	No. 3 Westinghouse motors.
The Springfield (Massachusetts) Street Railway	71	40	0.28	Double and single reduction equipment.

TABLE CXLI.—GIVING APPROXIMATE COST OF REPAIRS AND MAINTENANCE AND OTHER DATA ON LONG AND SHORT CARS, ST. LOUIS, MO.

Items.	Long Car.	Short Car.
Cost of motor repairs in pounds per annum ...	60	38
,, ,, shillings per day ...	3s. 6d.	2s. 1d.
Cost of truck repairs in pounds per annum ...	48	23
,, ,, shillings per day ...	2s. 9d.	1s. 3d.
Average speed in miles per hour ...	9.6	8.6
,, Board of Trade units per car mile ...	1.30	1.00
Time required to stop, in seconds ...	10	$7\frac{1}{2}$
,, ,, regain speed in seconds ...	11	6
Number of seats ...	36	28
Total crowded capacity... ...	110	80
Weight empty in pounds ...	23,500	16,000
Percentage of weight on driving wheels when car empty ...	70	100
Weight in pounds per seat, car empty ...	653	572
,, ,, ,, seats full ...	782	702
,, ,, ,, car crowded ...	1,050	943

*

TABLE CXLII.—AVERAGE COST OF REPAIRS AND MAINTENANCE OF ROLLING STOCK IN PENCE PER CAR-MILE IN AMERICA.

	Pence per Car-mile.
Repairs and maintenance of four-wheel trucks and equipment	0.16
Repairs and maintenance of four-wheel bogie and equipment	0.21
Cleaning and inspection of set of four-wheel trucks and equipment ...	0.105
Cleaning and inspection of set of four-wheel bogie trucks and equipment ...	0.141
Repairs and maintenance to double motor equipment ...	0.36
Repairs to car bodies ...	0.24

A very important part of a tramway is necessarily the permanent way, and figures are very difficult to obtain and are not very reliable, as electric traction has been operated scarcely a sufficient time to afford safe figures; besides which, in nearly all cases, directly after the introduction of electricity, most of the companies entirely renewed their permanent way.

TABLE CXLIII.—DATA OF MAINTENANCE AND DEPRECIATION RESULTING FROM GERMAN EXPERIENCE.

	Pence per Car-mile.
Car cleaning ...	0.3 to 0.6
Oil, grease, and waste ...	0.154
Repairs to trucks, motors, and cars ...	0.384 to 0.546
„ engines and machinery of power plant ...	0.144 „ 0.250
Repairs and maintenance of overhead line ...	0.096 „ 0.115

TABLE CXLIV.—DURABILITY OF RAILROAD TIES, FROM A REPORT OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

	Years.
White oak and chestnut oak ...	8
Chestnut ...	8
Black locust ...	10
Cherry, black walnut, locust ...	7
Elm ...	6 to 7
Red and black oaks ...	4 to 5
Ash, beech, and maple ...	4
Redwood ...	12
Cypress and red cedar ...	10
Tamarack ...	7 to 8
Longleaf pine ...	6
Hemlock ...	4 to 6
Spruce ...	5

Tables CXLV. and CXLVI. give some of the results as to life and maintenance cost for permanent way. It will be seen that these costs differ very widely, and little reliability can be placed on them, as in many cases not only maintenance but also the entire renovation of the track is charged for under the same heading.

TABLE CXLV.—LIFE OF RAILS ON ELECTRIC LINES IN AMERICA.

Name of Town.	Pounds per Yard.	Number of Cars Passing per Day.	Weight of Cars in Pounds.	Duration of Rails.
				years.
Cincinnati	52	250	17,000	6
Large town	72	400 to 650	15,000 to 17,000	5
Town in Missouri	64 to 78	300 ,, 500	12,000 ,, 16,000	5½ to 7

TABLE CXLVI.—APPROXIMATE COST OF MAINTENANCE OF TRACK AND ROAD BED ON SOME AMERICAN ELECTRIC ROADS.

Name of Town.	Per Mile of Single Track.	Per Motor Car Mile Run.
	£	d.
Minneapolis and St. Paul	60	0.281
Denver	35	0.200
West End, Boston	530	1.56
Kansas City	153	0.32

Table CXLVII. gives some of the results obtained in Europe, as well as some interesting figures as regards maintenance of cars and overhead line.

TABLE CXLVII.—COST OF MAINTENANCE OF TRACK, CARS, AND OVERHEAD LINE.

Items.	Track and Road Bed.		Cars.				Overhead Line per Car-Mile.
			Car Body.		Truck and Running Gear.		
	Per Mile of Track.	Per Car-Mile Run.	Per car Body.	Per Car-Mile.	Per Truck.	Per Car-Mile.	
	£	d.	£	d.	£ s. d.	d.	d.
Average for several English horse lines ..	500	0.6	—	—	—	—	—
Geneva trams	—	1.40	—	0.230	—	0.476	—
Hamburg electric	132	0.20	11	—	12 12 0	0.316	0.058
Zurich electric	—	0.158	—	0.213	—	0.120	0.024

In working out the power required in the power station it is necessary to know the amount consumed per car-mile run. In this connection, in Table CXLVIII., for which we are indebted to the courtesy of Professor Mengarini, of Rome, a very interesting series of figures is set forth which show, that for lines having at least 10 motor cars, even with heavy gradients of 1:10, an allowance of one Board of Trade unit per car-mile is

quite safe in estimating the quantity of power which will be required: a point which is of very great interest, where, as in many instances, the power is not generated by the tramway company, but is bought from a lighting or power station, and a guarantee of an annual minimum consumption has to be given. Table CLIII. shows the results obtained in the large Hamburg lighting and power station, and is interesting from the fact that a large battery of accumulators is run in parallel on the lighting and tramway circuits. It shows that in large plants accumulators give a very good efficiency, the highest efficiency obtained in this instance being over 78 per cent. Table CLII. gives an approximate idea of the cost of parts composing power plants, and is safe for working out preliminary estimates, where only few figures are obtainable.

TABLE CXLVIII.—Average Power Consumption on Electric Line, Maximum Grade 1 : 10.

Average Speed, 8 miles per hour.

Number of Cars Running.	Number of Days Test Lasted.	B. T. Units per Car-mile.
1	4	2.185
2	4	1.585
3	1	1.008
4	3	1.116
6	5	1.147
7	4	1.068
8	5	1.034
8.3	31	0.992
8.2	31	1.034
8.8	31	1.075
9	29	1.046

Current consumption on 10 per cent. grade, 50 to 70 amperes at 500 volts. Maximum gradient, 1 : 10. Sharpest curve, 48 ft. radius.

TABLE CXLIX.—Power Consumption on Various European Lines per Car-Mile.

Name of Company.	Grade.	Average B.T.U. per Car-Mile.	Average Speed per Hour.	Pounds of Coal per Car-Mile.
			miles	lb.
Aix-la-Chapelle	1 in 11	.589 to 1.236	8	3.5 to 6.9
Gera	..	.975	8	21 (lignite)
Hamburg	..	.902	6 to 12	3.21
Brussels, La Petite Espinette	1 in 25	1.200 (heavy cars)	16	
Zwickau	1 ,, 25	.670 on level, 1.230 on incline	..	4.6 to 4.9
Hanover	Level	.681	6 to 8	
Konigsberg	1 in 24	.608	8	
Dortmund	1 ,, 40	·576	7 to 8	
Lubeck	1 ,, 20	.592	8	
Strasburg	1 ,, 70	.688 (large car)	8	
Rome	1 ,, 10	1.056	7 to 8	
Zurich	..	.782	9	
Baden-Vöslau	..	0.490	8	3.91
Bristol	1 in 15	1.000	8	7

TABLE CL.—COST OF POWER ON VARIOUS EUROPEAN LINES.

Name of Town.	Cost of Production per Board of Trade Unit.	Cost at which Sold to Tramway Company.	Quantity Company Guarantee to Buy.	Motive Power.
		d.		
Aix-la-Chapelle (*a*)	..	1.44 to 1.38	1,500,000	Steam
Gera	1.32	..	..	,,
Hamburg (*b*)	0.94	1.24	2,500,000	,,
Brussels	1.09	..	..	,,
Hanover	0.84	..	..	,,
Rome	..	1.77	..	Water
Dresden (*c*)	0.96	1.56	..	Steam
Geneva	..	1.15	500,000	Water
Baden-Vöslau	1.64	..	..	Steam

(*a*) Electric Supply Company pays 7.68d. for every car-mile which tramway company prevented from running through its fault.
(*b*) Electric Supply Company pays 9.6d. for every car-mile which tramway company prevented from running through its fault.
(*c*) Corporation pays 8d. for every car-mile which tramway company prevented from running through its fault.

TABLE CLI.—PRICES OF LUBRICANTS IN AMERICA.

		s.	d.
Sperm oil	per gallon	4	6
Neatsfoot	,,	4	1
Tallow oil	,,	2	10
Lard oil	,,	2	10
Greases	per pound	1	0
Heaviest mineral oil	per gallon	3	1
Medium machinery oil	,,	2	0
Light lubricating oil	,,	1	0
Crude well oils	,,	0	9
Kerosene (unrefined)	,,	0	5

TABLE CLII.—APPROXIMATE COST OF PARTS COMPOSING POWER PLANT.

		£	s.	d.
Cost of railway generator per kilowatt	—	6	0	0
,, three-phase machinery per kilowatt	—	7	0	0
,, steam plant complete, engines, boilers, and all accessories for high-speed engines	9*l* to 11*l*.		—	
Cost of steam plant complete for Corliss engines	13*l*. to 15*l*.		—	
Horizontal return tubular boilers per horse-power (30 lb. of water evaporated)	—	2	0	0
Water-tube boilers for high-pressure per horse-power	3*l*. to 4*l*.		—	
Lancashire boilers for high-pressure per horse-power	—	3	10	0
Cost of Corliss engine, including piping and foundations per horse-power	—	5	10	0
Cost of lightly-built engine-house per horse-power	—	1	0	0
Cost of feed pumps and injectors per horse-power	—	0	7	6
Cost of corrugated iron power station, approximate, per superficial foot	—	1	0	0

TABLE CLIII.—POWER, COST, MAINTENANCE, AND EFFICIENCY FIGURES FOR HAMBURG, 1895.

Months.	B.T.U.	Efficiency of Cells.	Loss in Cells in Percentage of Total Output.	B.T.U. on Cars.	Average B.T.U. per Car Mile.	Percentage of Loss in Feeders.	Total Efficiency at End of Feeder.	Maximum Daily B.T.U. produced.	Average Daily B.T.U. produced.	Maintenance. Cost per Unit Sold.	Coal per B.T.U.	Oil per B.T.U.	Total Cost of Production.	Coal Burnt per B.T.U.
April	381,179	86.3	1.4	227,864	.755	20.1	78.2	16,021	12,706	.092	.54	.057	1.28	4.145
May	372,780	83.8	1.5	228,754	.696	20.0	78.0	13,312	12,025	.072	.52	.055	1.22	4.079
June	415,643	82.2	1.3	279,880	.736	18.4	80.0	16,764	13,408	.171	.45	.045	1.22	3.660
July	423,473	84.9	1.0	288,274	.721	19.5	79,3	16,114	13,660	.070	.39	.049	.99	3.572
August.. ..	441,173	84.0	1.3	307,215	.728	15.0	83.1	17,062	14,231	.084	.29	.050	.87	3.351
September ..	511,539	83.4	1.2	328,206	.724	17.3	81.2	18,584	17,051	.100	.44	.040	.96	3.550
October ..	604,341	87.7	0.9	346,257	.734	17.9	80.6	21,537	19,495	.118	.37	.040	.87	3.550
November ..	657,002	86.8	1.0	360,786	.742	17.3	81.5	24,558	21,901	.099	.35	.043	.84	3.417
December ..	695,263	87.3	0.9	385,318	.763	14.8	84.3	25,632	22,428	.093	.35	.038	.84	3.417

A careful study of the Tables given will enable fair conclusions being drawn for any particular case in point.

CHAPTER XXXV.

STATISTICS AND WORKING EXPENSES.

SINCE the first pages of this book were written, Electric Traction has been advancing by leaps and bounds, and there is little doubt that it will supersede every other mode of propulsion as far as tramways and light railways are concerned. The well-known American *Street Railway Journal,* which is not tied to any particular interest, but which simply represents public opinion in America, commenting on the introduction of the cable system into Edinburgh, said in one of its leaders, in April 1896, "The cable system seems to be coming into use in England at about the time when America is discarding it."

English local authorities are becoming alive to this fact, and the recent reports put in by the committees of Glasgow, Leeds, Plymouth and Belfast, after visiting continental installations, are wholly favourable to the introduction of electric traction and the trolley system. They have returned convinced that it is the only rational solution of the problem.

To quote another leader in the same issue of the *Street Railway Journal,* "The evidence is accumulating to such a degree as to be well-nigh conclusive that our former ideas as to the comparative economy of electric and cable cars in streets of great traffic density will have to be revised. Electricity is master of the field. Electric cars on the same routes make more money per car mile than cable cars, and, we think, can be operated in these days of cheap and good electrical machinery at as small a sum per car mile."

Denver, Minneapolis, Baltimore, San Francisco, Los Angeles, Philadelphia, Pittsburgh and St. Louis have thrown away enormous investments in road bed and machinery in order to adopt the overhead or trolley wire system. It is actually under consideration to substitute electricity for the cable down Broadway, New York. No doubt one of the great advantages of electricity over the cable is its practically indefinite power for expansion at relatively small cost, and as the *Street Railway Journal* remarks, "As long as English tramroads aim to serve only the thickly-populated districts,

they will fail to become the great agents for sociological improvement which the electric railways in this country have been and are." The facts and figures set out in the "Report of the Railroad Commissioners of the State of Massachusetts," compared with results obtained in Europe, show that Europe is, if anything, a more favourable field for electric traction than even America, and that the stock phrase as to conditions being so different does not hold good as regards the advantages to be reaped by the introduction of the trolley system.

In 1887 there were in the State of Massachusetts 42 tramways with 470 miles of track all operated by horses. There are now 70 tramways with 1,100 miles of track, all but 62 miles being equipped for electric power. In the whole United States in 1887 there were 13 electric street railways with scarcely 100 cars. There are now nearly 900, owning 13,000 miles of track, and running some 36,000 cars, and the total capital investment in these amounts to over 100 million pounds. Table CLIV. will give an idea of the rapid increase of electric traction in the State of Massachusetts.

TABLE CLIV.—NUMBER AND MILEAGE OF STREET RAILWAY COMPANIES IN THE STATE OF MASSACHUSETTS.

Years.	Total Length of Main Track.	Horse Lines.	Electric Lines.
	miles	miles	miles
1888	533.59	533.59	0.0
1889	574.17	523.65	50.52
1890	612.38	451.52	160.86
1891	672.45	383.42	289.03
1892	754.85	258.55	496.30
1893	874.14	163.06	711.08
1894	928.84	103.87	824.97
1895	1,077.98	61.80	1,016.19

Wherever electric lines parallel steam lines, the electric lines flourish and the suburban traffic on the steam lines decreases enormously.

The most striking instance of such diversion of passenger traffic has occurred on the 10 miles between the cities of Minneapolis and St. Paul. At the time of the opening of the electric installation of the Twin City Rapid Transit Company, which controls the tramways of these cities, each of the two railroads connecting St. Paul and Minneapolis ran a local train every hour, in addition to the many through trains for more distant points, which also carried local passengers. Within six months after the opening of the electric tramway, both railroads entirely discontinued their local

interurban train service. The advantages afforded by the electric railway were too great to be overcome. The steam roads taken together ran half-hourly trains, with fares of $7\frac{1}{2}$d. on a season ticket, 1s. 3d. for a single trip, and 2s. 1d. for a round trip; and the time was 25 minutes. The electric cars were run every six minutes, the fare was 5d. (with the privilege of free transfer from and to the city lines), and the time was 50 minutes. The difference of time in favour of the steam roads was overbalanced not only by the greater frequency of service and the lower fare on the electric railway, but by the insuperable advantage which the latter possessed in that passengers could take its cars at the most convenient point on any street traversed by the electric lines in the one city, and be carried to a like convenient point in the other.

That electricity can be operated successfully on main lines has now abundantly been proved by the success of the Nantasket Beach system. The conclusion to which the directors of the New York, New Haven and Hartford Railway have arrived at is: "That the experiment has demonstrated that power generated in a stationary plant and transmitted by electrical agency can be successfully used in the operation of a standard railroad. The current expenses for fuel indicate that this result is economically obtained. Power thus transmitted is capable of indefinite subdivision, and is therefore most available for frequent car service." Other reasons for the superiority of electricity for traction are given by the Railroad Commissioners in their report:—

"Electricity is clean, easily managed, and wonderfully flexible. Cars can be started and stopped quickly, can be run as close together as the speed will permit, so that the full capacity of the track may be utilised, and can be run at greater speed than by horse-power, where such speed is admissible.

"So in the case of elevated and underground railways, which are usually built only for urban or suburban service, electricity has many advantages over steam, and is undoubtedly on the whole the better motive power.

"The weight of opinion, if not the only opinion, among electrical experts seems to be that overhead conduction is the only practical method for surface of roads. For elevated and underground railways, a third rail or a conduit may be used."

There is little doubt from the experience obtained in America that on lines such as our metropolitan system of tramways and underground railways, and such as the London *réseau* of steam suburban lines, electricity

will work wonders. Where a steam railroad service resembles in general characteristics that of a street railway, its conversion to the use of electricity is invariably exceedingly successful. The most economical field for the use of electrical power is found where a considerable volume of local and short distance travel is to be encountered, which justifies the running of numerous passenger trains at short and regular intervals in order that the load may be uniformly distributed over the line.

The cost of doubling and electrically equipping the Nantasket Beach line, which is 4.83 miles in length, was £60,000.

The enormous traffic carried by the tramways of Massachusetts is remarkable: 260 million passengers were carried last year, which is equal to three times the total number of passengers carried by the steam railroads of that State.

The average cost of its tramways per mile of track was, at the end of last year, about £4,800 for construction, £2,100 for equipment, and £2,800 for land and buildings. Table CLV. is interesting as showing the volume of traffic carried, and the increase of passengers per trip for the last eight years. Table CLVI. shows that by the introduction of electricity the percentage of operating expenses to receipts has steadily decreased, and that the dividend-earning capacity has, of course, also steadily increased.

TABLE CLV.—State of Massachusetts. Volume of Traffic.

Years.	Total Passengers carried.	Total Car-Miles run.	Total Round Trips run.	Average Passengers per Trip.
1888	134,478,319	23,244,767	3,220,578	42
1889	148,189,403	24,259,491	3,446,769	43
1890	164,873,846	26,516,937	3,764,816	44
1891	176,090,189	27,670,166	3,958,455	44
1892	194,171,942	29,678,036	4,168,458	47
1893	213,552,009	34,507,282	4,481,171	48
1894	220,464,099	36,722,978	4,662,786	47
1895	259,794,308	43,655,560	5,179,234	50

TABLE CLVI.—State of Massachusetts. Percentage of Operating Expenses to Gross Income from Operation.

Years.	Percentage of Expenses to Income.	Years.	Percentage of Expenses to Income.
1888	81.07	1892	71.74
1889	78.40	1893	69.26
1890	74.80	1894	69.51
1891	76.13	1895	68.93

Table CLVII. shows the increase of earnings both gross and net, and the decrease in operation expenses during the last eight years. The dividend declared last year and paid on the total capital expenditure was 5.76 per cent., computed on the mean amount of capital stock outstanding at the beginning and end of last year. The West End Street Railway Company of Boston, the largest electrical installation in the world, paid 8 per cent. on preferred stock and $6\frac{1}{2}$ per cent. on common stock. Table CLVIII. shows the enormous increase of electric traction in the last eight years, and Table CLIX. shows the decrease in total running expenses, and the increase in net earnings per car mile. A great number of these lines put in their electrical plant at a time when this work was extremely expensive, being practically in an experimental stage, and were forced to renew after only a short period of service.

TABLE CLVII.—MASSACHUSETTS. GROSS AND NET EARNINGS FROM OPERATION PER MILE OF MAIN TRACK OWNED, AND PER ROUND TRIP RUN.

Years.	Gross Earnings.	Average per Mile owned.		Average per Round Trip.		
		Expense of Operation.	Net Earnings.	Gross Earnings.	Expense of Running.	Net Earnings.
	£ s. d.	£ s. d.	£ s. d.	s. d.	s. d.	s. d.
1888	2,625 0 0	2,128 5 8	496 14 4	8 9	7 1	1 8
1889	2,689 9 0	2,108 15 8	580 13 4	8 11	7 0	1 11
1890	2,798 0 7	2,092 19 7	705 1 0	9 1	6 10	2 3
1891	2,704 16 10	2,059 2 3	645 14 7	9 2	7 0	2 2
1892	2,664 4 1	1,911 6 7	752 17 6	9 8	6 11	2 9
1893	2,643 10 3	1,761 9 10	782 0 3	9 11	6 10	3 1
1894	2,457 6 1	1,707 18 5	749 7 8	9 10	6 10	3 0
1895	2,489 2 5	1,715 14 5	773 8 0	10 6	7 2	3 4

TABLE CLVIII.—MASSACHUSETTS. EMPLOYÉES AND EQUIPMENT.

Years.	Employées.	Cars.	Horses.	Electric Motors.
1888	5,531	2,588	11,391	...
1889	6,302	2,942	11,817	...
1890	6,246	3,247	11,241	...
1891	6,449	3,494	10,640	...
1892	7,185	3,679	6,734	...
1893	8,070	4,040	3,531	3,013
1894	7,461	4,058	2,014	3,906
1895	8,048	4,426	1,436	4,704

TABLE CLIX.—MASSACHUSETTS. GROSS AND NET EARNINGS FROM OPERATION PER CAR MILE RUN.

Years.	Expense of Running. Pence.	Net Earnings. Pence.
1888	11.72	2.74
1889	12.66	2.60
1890	11.76	3.75
1891	12.01	3.77
1892	11.67	4.59
1893	10.71	4.75
1894	10.37	4.54
1895	10.25	4.62

On a total of 260 million passengers carried, the number of accidents is remarkably small. The total number of injuries was 1,507, of which 25 only proved fatal. Of the persons injured, 898 were passengers, and seven eventually died. Most of the accidents were due to the carelessness of passengers in getting on and off the cars. The number of injuries to employés was 45, of which none were fatal, and the number of injuries to the general public was 564, of which 18 were fatal. To put it in another way, one person was injured for every 289,302 passengers carried, and one person was killed for every 37,113,472. The cars ran an average of 77,402 miles per accident, and 2,425,308 miles per fatality; or the total number of passengers carried in the State of Massachusetts, 155,231,506 were carried by the "West End" company, or nearly 60 per cent. of the whole number carried in the State. The State increase of passengers carried in 1895 over 1894 was 40,500,000, of which 18,200,000 fell to the share of the West End road.

It is a mistake to suppose that by building an electric road anywhere and anyhow a fortune is sure to be made, but it is an unquestionable fact that by the introduction of electricity a very rapid growth in the volume of traffic takes place, and that a very remarkable reduction is made in the ratio of operating expenses to gross earnings. This is shown in the previous tables. There is now no longer any possibility of doubt that there is no known method of conveyance by which such large numbers of persons can be transported through the streets with so much convenience and safety to themselves and to the public at large, with so little noise, confusion, and dirt, and with so little obstruction and wear and tear on the streets, as by the electric trolley-wire system. 425,292 passengers are carried daily on the street railways of Boston, which is equal to about 86 per cent. of the total population of that city.

TABLE CLX.—Expenses of Twin City Rapid Transit Company in Pence per Car-Mile.

Items.	1893. Pence per Car-Mile.	1894. Pence per Car-Mile.	1895. Pence per Car-Mile.
General expenses	.454	.320	.275
Maintenance of equipment	.872	.540	.336
Maintenance of way and structure	.477	·346	.281
Conductors' and motor-men's wages	2.182	1.933	1.830
Inspectors' and transfer agents' wages ...	.132	.075	.043
Miscellaneous car expense	.159	.121	.112
Station expense, labour, &c....	.377	.239	.215
Fuel for cars and stations	.077	.050	.043
Electric lighting "supplies"...	.006	.005	.002
Oil and waste for cars	.017	.010	.010
Electric supplies for cars	.018	.015	.016
Stationery and printing for stations ...	.011	.010	.009
Transfers and transfer supplies	.015	.016	.014
Strike, additional expense	.012	.003	—
Cost of maintaining power stations	1.105	.945	.697
Machine shop expense	.176	.120	.105
Insurance...	.091	.087	.066
Injuries and damages...	.470	.559	.391
Legal expenses	.090	.089	.072
Contingent expenses	.052	.073	.112
Interest on bonds and $6\frac{1}{2}$ per cent. certificates	2.915	3.454	3.143
Interest on floating debt	.031	.134	.252
Taxes	.075	.277	.237
Total operating expenses per car-mile ...	6.090	4.748	3.988
Total expenditure per car-mile ...	9.814	9.421	8.261

Number of motor cars in 1895	580
„ trailer „	320
Miles of track owned in 1895	225

TABLE CLXI.—Twin City Rapid Transit Company, St. Paul-Minneapolis.

	Pence.
Gross earnings in 1892 per car-mile	13.36
„ „ 1895 „ „	16.21

Year.	Ratio of Operating Expenses to Receipts. Per cent.
1892	61.28
1893	58.40
1894	44.91
1895	43.10

*

Table CLX. is a remarkable instance of decrease in working expenses and increase in receipts, by the introduction of electrical traction on the overhead system. When this line was first laid down, the cable system had been decided upon, and, in fact, a great deal of the plant had been ordered and purchased. President Lowry, of the Twin City Rapid Transit Company, however, made up his mind, after careful consideration, that the trolley system was the best. Nearly the whole cable plant was scrapped and the trolley plant put in, with the result shown in Table CLX. It will be seen that the total operating expenses, as well as the whole of the expenditure, have been steadily decreasing year by year, and that while in 1892 the receipts were 13.36 pence per car mile, in 1894 these had risen to 16.31 pence, and that the ratio of operating expenses to receipts, which in 1892 was 61.28 per cent., had decreased in 1895 to 43.1 per cent., as shown in Table CLXI.

TABLE CLXII.—DENVER CONSOLIDATED TRAMWAY COMPANY. DETAILED STATEMENT OF EXPENSES FOR 1895 IN PENCE PER CAR-MILE.

Transportation.

	Pence.
Superintendence	.047
Wages, trainmen	2.632
Car despatching	.002
Secret service	.040
Transfers and agents	.065
Flag and switchmen	.008
Car license	.027
Mail service	.001
Uniform expenses	·003
Total	2.825

Power House Expense.

	Pence.
Superintendence	.009
Engineers, foreman, and oilers	.186
Dynamo tenders	.050
Fuel	.759
Water supply	.000
Machinery and boiler repairs	.049
Oil, grease, and waste	.027
Dynamo repairs	.014
Total	1.094

Maintenance of Way.

	Pence.
Track repairs	.146
Paving repairs	.001
Track oilers	.042
Overhead line repairs	.056
Track cleaning	.017
Total	0.262

Maintenance of Cars.

	Pence.
Superintendence and clerks	.022
Car repairs	.219
Armature and field repairs	.321
Electrical attachment	.056
Gears and pinions	.055
Oilers and wipers	·032
Car cleaning	.035
Car lighting	.260
Car moving	.003
Oil, grease, and waste	.214
Total	1.217

General Expense.

	Pence.
Salaries	.278
Incidentals	.013
Insurance	.089
Light and heat	.022
Office expense	.014
House expense	.031
Building repairs	.010
Stationery and printing	.028
Rent	.011
Telephone service	.020
Tool repair	.004
Wreck wagon and signal system	.009
Stable expense	.029
Damage	.030
Legal expenses	.067
Advertising	.002
Total	0.657

Total expenses per car mile ... ... 6.055 pence.

Car miles run	3,803,078
Passengers carried	14,505,813
Miles of track	99.29
Total number of cars owned	296

Table CLXII. gives the detailed working expenses per car mile of the Denver Consolidated Tramway Company. This is one of the cases in which the company has taken up their cable roads and replaced them by the trolley, the result being highly satisfactory. Table CLXIII. gives the operating expenses of the West End Company of Boston. It will be noted that these expenses are very high, but it must be borne in mind in this connection that the conditions of Boston are exceptional. In several parts of the town the streets frequently become flooded, and yet car service must not be interrupted. Besides this, the whole track has had to be entirely renewed, and a great part of this expenditure has been counted into working expenses. In addition to this, the West End road was the first line to be equipped entirely on the overhead system, and the first electrical equipment had to be replaced entirely by more modern plant, nearly all of which expenses have been charged to operating cost. It will be seen by looking at the Table that maintenance of track and maintenance of electrical equipment are very high. Nearly all the car-bodies have also been entirely rebuilt, this expenditure being chiefly charged as maintenance.

TABLE CLXIII.—West End Street Railway Company, Year 1895.

Pence per Car Mile.

	Pence.
For general expenses ...	1.3390
Maintenance of track ...	1.5600
,, ,, buildings ...	.1150
,, ,, car and vehicles ...	1.6308
,, ,, horse equipment ...	.2698
,, ,, electric equipment ...	1.0595
Road and snow expenses ...	.3385
Transportation expenses ...	6.0823
Injuries and damages ...	.0541
Total ...	12.4490

Passengers carried ...	155,231,506
Miles of track owned ...	274.8
Car-miles run ...	22,180,125
Percentage of car mileage of lines still operated by horses ...	4.85

Table CLXIV. gives the working expenses of the Montreal Electric Street Railway for 1895.

Tables CLXV. and CLXVI. give some data of the North Chicago Railway. Here again it will be observed how much the ratio of the

working expenses to receipts is decreased by the introduction of the trolley system. Particular attention is called to the fact that, in the case of the North Chicago Railway Company, it costs more to work the cable section than the electric section per car mile. In the case of the Chicago City Railway, attention is called to the fact (Table CLXVI.) that whereas the expenses per car mile for cable and horse have risen, those of the electric lines have decreased.

TABLE CLXIV.—Giving Working Expenses of Montreal Street Railway, 1895.

	Per car mile.
Transportation	2.69d.
Motive power	.64
Maintenance	1.01
General Expenses	.74
	5.08d.

TABLE CLXV.—North Chicago Railway, 1895.

1894. Run by horses, ratio of operating expenses to receipts	54.33 per cent.
1895. ,, trolley, ,, ,, ,, ,,	48.71 ,,
Electric trolley line operating expenses in 1895, per car mile	5.41d.
Cable ,, ,, ,, ,, ,, (same company).	6.15d.

TABLE CLXVI.—Chicago City Railway, 1895.

Passengers carried	88,806,461
Earnings on capital stock	14.41 per cent.
Capital stock	£2,463,054 3s. 9d.
Car mileage on cable lines	14,872,580
,, ,, ,, horse	1,452,560
,, ,, ,, electric	5,526,760

	Pence per car mile. 1894.	1895.
Cable	4.912	5.044
Horse	12.509	15.049
Electric	8.327	7.288

Mileage of cable lines	34 miles
,, ,, electric ,,	117 ,,
,, ,, horse ,,	9 ,,
Cars owned	1,785

Table CLXVII. gives detailed working expenses of electric railways in the State of Connecticut, and it is taken from the Report of the Railroad Commissioners of that State.

TABLE CLXVII.—WORKING EXPENSES IN PENCE PER CAR-MILE FOR SEVERAL AMERICAN ELECTRIC STREET RAILWAYS, FROM RAILROAD COMMISSIONER'S REPORT OF THE STATE OF CONNECTICUT, 1895.

Name of Company.	Repairs to Road-bed and Track.	Repairs to Cars.	Repairs to Electrical Equipment of Cars.	Repairs to Electric Line Construction.	Repairs to Buildings and Fixtures.	Removal of Snow and Ice.	Horses, Renewal and Fodder.	Electric Power.	Trainmen's Wages.	Insurance and Legal.	Loss and Damages.	Salaries and Other Wages.	General and Other Expenses.	Ratio of Working Expenses to Receipts.	Total Expense per Car-Mile.
	pence	pence	pence	pence	pence	pence	pence	pence	pence	pence	pence	pence	pence	per cent.	pence
Central Railway and Electric Company, New Britain	85	.89	.07	—	—	.10	.04	1.97	2.58	.35	—	.79	—	71.3	7.64
Danbury and Bethel Street Railway Company	.06	.14	.06	—	—	.06	.89	.69	2.18	.29	—	.30	.11	71.9	4.78
Hartford and W. Hartford Street Railway Company	.09	.11	.04	.02	.005	.26	—	1.32	2.15	.04	.04	.31	.37	68.5	4.75
Meriden Electric Railroad	.06	.21	.44	.09	.005	.09	—	.95	3.22	.35	—	—	.70	72.1	6.11
Middleton Street Railway Campany ..	.06	.04	.02	.01	.02	.09	.05	2.00	3.05	.36	—	.63	.42	67.6	6.75
Newhaven and Centerville Street Railway Company	.005	.07	.02	.04	.01	.04	.58	.72	3.09	—	—	.32	.04	51.8	4.93
New London Street Railway Company	.44	.32	.28	.06	.005	.03	—	2.04	2.45	.37	—	.80	.47	58.6	7.26
Norwalk Tramway Company	.25	.12	.15	.07	.01	.04	—	1.59	2.38	.31	.04	.78	.58	68.7	6.32
Canterbury Traction Company ..	.25	.20	.32	.11	.01	.15	.04	1.68	3.45	.20	.03	.35	.29	60.9	7.08

Table CLXVIII., taken from the reports of the Brooklyn Heights Railroad Company, is interesting as showing the increase in railway work and the decrease of the ratio of expenses to receipts.

TABLE CLXVIII.—REPORT OF THE BROOKLYN HEIGHTS RAILROAD COMPANY.

Items.	1895.			1896.		
	£	s.	d.	£	s.	d.
Gross earnings	844,206	2	0	890,081	15	0
Operating expenses	595,792	18	6	521,505	9	1
Net earnings	248,413	3	9	368,576	6	6
Income from other sources	46,015	13	3	48,458	4	8
Gross income	294,428	17	0	417,034	11	2
Fixed charges and taxes	432,476	19	4	426,015	13	10
Ratio of expenses to receipts	67.8 per cent.			57 per cent.		

The records of New York City as regards the passenger traffic on the tram lines and on the overhead lines is of interest, as showing the enormous increase which has taken place of late years. Thus, in 1865 there were altogether eleven lines of street railways, which carried altogether 79,618,818. In 1875, ten years later, this figure had nearly doubled, and had become 140,588,793. In 1883, when some of the elevated roads had been constructed, the total number of passengers carried was 266,164,236, and in 1893 this figure had again nearly doubled, and had become 453,658,964.

Table CLXIX. shows the enormous increase in electric traction in America during the last few years, and the corresponding decrease in every

system, both cable, horse, and steam. Attention is called to the fact that whereas the mileage up till 1894 had steadily gone on increasing, from that day till now it is on the decline; and it will be seen that out of the total number of street cars running in America 83 per cent. run on electric roads. Table CLXX. is of interest, as showing the low ratio of working expenses to receipts of some large electric lines of America.

TABLE CLXIX.—PROGRESS OF ELECTRIC, HORSE, AND CABLE LINES IN AMERICA, 1890 TO 1895.

Street Railways.	1890.	1891.	1892.	1893.	1894.	1895.
Mileage.						
Total	9,037	10,599	11,665	12,186	12,527	14,932
Electric	2,523	4,061	5,939	7,466	9,008	12,583
Horse	5,400	5,302	4,460	3,497	2,243	1,232
Cable	510	594	646	657	662	599
Steam and various ...	604	642	620	566	614	519
Number of Cars.						
Total	32,108	35,877	37,399	40,499	41,668	49,369
Electric	5,592	8,892	13,415	18,233	24,849	36,121
Horse	21,970	21,798	19,315	16,845	11,507	5,420
Cable	3,795	4,372	3,971	4,805	4,673	4,871
Steam and various ...	751	815	698	616	639	2,957

The figures in this Table have been taken from that exceedingly interesting book, "Street Railway Investments," which is published annually by the *Street Railway Journal,* and the cost of the road equipment given in this Table can naturally be taken as only approximate; besides which their meaning is not quite clear, as in some cases in the equipment cost the cost of all land and buildings is included, and in other cases it is not.

Now if we compare these figures to the figures obtainable of English tramways, which have been taken from "Duncan's Manual," we find that the average working of horse tramways comes out slightly above 9d. per car-mile, and that the average ratio of working expenses to receipts is nearly 80 per cent. If we take steam lines in England, Table CLXXI. shows at a glance the enormous working expenses incurred by this mode of traction, and if we compare the horse lines we find that the expenses are still exceedingly heavy, and that in both cases the ratio of working expenses to receipts is always above 60 per cent.; whilst in the American lines given in Table CLXX. we find that this ratio is always lower, or in other words that a very much larger percentage of the earnings is available for dividends to be paid to shareholders.

TABLE CLXX.—Giving Cost of Equipment per Mile, Mileage, and Ratio of Working Expenses to Receipts of some large American Lines.

Name of Town.	Miles of Line.	Cost of Equipment per Mile.	Ratio of Working Expenses to Receipts.
		£	per cent.
Albany	34	11,800	60
Baltimore	101	—	54
Lynn and Boston	153	8,000	57
Buffalo	143	16,400	48
Montreal	75	10,900	59
Toronto	80	23,800*	50

* This includes all buildings and land.

Table CLXXI. shows clearly why horse and steam lines do not pay. It is not only the heavy working expenses of the car, but the comparatively low receipts which leave a very small margin over for profits.

TABLE CLXXI.—Showing Working Expenses of some European Tramway Lines worked by Steam and Horses.

Name of Line.	Expenses per Car-mile.	Receipts per Car-mile.	Ratio of Expenses to Receipts.
English steam lines:	d.	d.	per cent.
Birmingham Midland	9.08	14.27	63.6
Burnley	12.43	19.38	64.2
Dudley	12.40	15.58	79.5
Huddersfield	14.00	—	88.8
English lines worked by horses:			
Belfast	8.42	11.35	74.1
Dublin United	9.52	12.84	84.0
North Metropolitan	9.99	12.53	79.8
Plymouth	12.15	11.00	104.8
Liverpool United	11.05	12.95	85.4
Newcastle	10.84	12.60	84.3
Foreign lines worked by horses:			
Frankfort	8.02	—	—
Marseilles	6.12	—	—
Magdeburg...	5.05	6.81	73.7
Gothenburg	5.80	7.38	78.6
Calcutta	8.92	9.48	91.8
Calais	7.55	7.94	91.9

Electric cars can run a much greater car mileage per day than horse or steam cars, and Table CLXXII. shows the average mileage on some European lines. Horse cars could not run half that distance. Table CLXXIII. is interesting in showing that, after electric lines have once got started their operating expenses rather decrease than increase.

TABLE CLXXII.—Mileage Run by European Electric Cars per Day.

	Miles.
Leeds ...	110
Marseilles	94
Buda-Pesth	75 to 100
Guernsey	70
Halle ...	71
Bristol...	113

TABLE CLXXIII.—Showing Decrease of Working Expenses on Electric Roads in Various Cities.

Halle:	1892	1893
Operating expenses per car-mile ...	2.90d.	2.79d.
Gera:	1892	1893
Car-miles run	379,335	381,857
Working expenses per car-mile ...	2.97d.	2.80d.
Frankfort-Offenbach:	1884	1890
Working cost per car-mile	8.26d.	4.08d.
Leeds, Roundhay Road:	1892	1894
Total working cost per car-mile ...	6.63d.	5.5d.
Bessbrook-Newry:	1887	1891
Cost of haulage per train-mile ...	4.2d.	3.94d.
	1891	1896
City and South London	7.70d.	4.69d.

It is somewhat difficult to obtain statistics of the working costs of European electric tramways. However, from a very considerable amount of data which have been collected, it may be said broadly that the average total working costs per car-mile (excluding interest on capital invested and taxes) rarely exceeds 5d. per car-mile run, and that the ratio of operating expenses to receipts averages is well under 60 per cent.

The electric railways of Bremen are operated at a cost averaging 28 per cent. less than the horse tramways of the same city.

The following Tables give the working expenses of some of the principal Continental electric lines. Great interest attaches to these figures, as they have been worked out from the official reports of the various tramway companies, who in no case have any particular interest in the adoption of any specified system of mechanical traction, but whose sole advantage lies in the adoption of that method which will assure the largest interest on the capital expended.

TABLE CLXXIV.—GIVING WORKING EXPENSES IN PENCE PER CAR MILE FOR HANOVER, 1895.

Management	.119
Wages and salaries and office expenses	.048
Train men	.684
Total	.851
Maintenance of uniform	.038
New uniforms	.058
Tickets	.042
Total	.138
Transportation.	
Motor-men	.641
Stokers	.156
Fuel	.382
Oil, grease and waste	.111
	1.290
Cleaning and maintenance of trucks and trolleys	.783
Maintenance of trolley line	.060
Maintenance of power house	.119
Maintenance of car	.121
Car cleaning	.038
Car lubrication	.006
Maintenance of track	.077
Cleaning snow and ice	.269
Maintenance of buildings	.031
Lighting and heating cars	.033
Maintenance of tools	.015
Accidents	.025
Total	1.577
Insurance	.013
Rent	.414
Maintenance of electric lighting	.006
Sick fund	.079
Taxes	.192
Various	.037
Total	.741

Grand total ... ... 4.597 pence.

No. of employés, 645.

Table CLXXIV. gives the working expenses of the Hanover tramways for the year 1895. This company when worked by horses scarcely paid a dividend of 1½ per cent., whereas last year, after having adopted electrical traction on some of its lines, it paid over 4 per cent. It is now engaged in equipping its remaining lines on the overhead system. It is true that in the centre of the town the local authorities will not yet allow an overhead wire—why, it is difficult to conceive—and in consequence of this the cars which enter the city each carry a battery of 208 five-plate Tudor accumulators, which are charged from the overhead trolley wire in parallel with the motors when the cars are running on the trolley system, and which are used to propel the cars when they leave the trolley wire and enter the centre of the city. The weight of the accumulators required for this service is nearly 2½ tons per car. As regards the question of maintenance and depreciation of the batteries, no figures are as yet obtainable, their manufacturers, the Hagen Company, having guaranteed their maintenance for a certain number of years at a fixed charge.

A similar system is also running on one or two short lines at Dresden. At the present moment there are in Hanover 13½ miles equipped on the electric overhead system, and 26½ miles still run by horses; the latter lines are, however, being transformed into trolley lines. The present capital of the company is composed of £225,000 ordinary shares, £125,000 preference shares, and £16,750 debentures. The capital has just been increased by £75,000. The number of electrical car miles run last year was 695,578.

Table CLXXV. gives the data relative to the Hamburg tramways, all of which by the end of 1896 were converted to the trolley system. This company paid in 1895 a dividend of 5 per cent. Out of the total 29 million passengers carried on the whole system, over 7 million were carried by electric cars; and whereas a perceptible decrease has taken place both in the passengers carried and receipts on the horse lines, the contrary has been found to be the case on the electric lines, where the number of passengers carried has increased 32 per cent. since the introduction of the electric system, and the electric car receipts have increased 34.9 per cent. The company employs 2,177 persons. The concession has 27 years more to run. The current for running the overhead line is taken from the electric light works which belong to another company, to which the monopoly of furnishing electricity both for lighting and power has been granted by the Corporation. Should this lighting company, through any fault of its own, stop the tramway company from running cars, it is bound

to pay ninepence to the tramway company for each car-mile which the latter has been unable to run. The tramway company in its turn guarantees to buy at least $2\frac{1}{2}$ million Board of Trade units per annum; the rate of charge being 1.56 pence per unit. Should $2\frac{1}{2}$ millions be exceeded, the price falls to 1.5 pence per unit. The Corporation pay the tramway company 20 per cent. of the cost of the current consumed, this being the amount paid by the lighting company to the Corporation for their concession, which reduces the actual cost per unit to the tramway company to 1.25 pence The amount of energy really consumed by the tramway company during 1896 was over 6,000,000 Board of Trade units.

TABLE CLXXV.—Working Expenses in Pence per Car-Mile of the Hamburg Electric Tramways.

Receipts	£170,248 10s.
Total passengers carried	29,164.237
Receipts per car-mile, 1894 and 1895	8.248d.
Ratio of expenses to receipts	48 per cent.

1895, *Cost per Car-Mile.*

Wages of conductors, motor-men, inspectors, &c.	1.327
Current per car-mile	.881
Repairs to motors, trucks and axles, and cleaning	.315
Lubricants and oils	.022
Inspection and supervision	.025
Maintenance of overhead line	.058
Renovation fund	.192
Sinking fund	.403
Interest on capital stock	.269
Amount paid to contractors for guarantee	.192
Amortisation of electrical equipment	.288
	3.972

Increase in receipts over previous year when lines were worked by horses	34 per cent.
Rolling stock (motor cars)	360
Closed trail cars	417
Open trail cars	25
Length of single track in miles...	103
Passengers carried by electric cars	7,108,973

Table CLXXVI. gives the working expenses of one of the electric lines now running in the city of Zurich, and which has been working for over two years, giving the greatest satisfaction.

TABLE CLXXVI.—WORKING EXPENSES OF ZURICH TRAMWAYS 1894 IN PENCE PER CAR-MILE.

	Pence per Car-mile.
Management—salaries	.325
Materials	.054
Maintenance of track, wages, and supplies	.263
Conductors and inspectors	.995
Materials, lighting, &c.	.055
Engine-drivers and stokers	.294
Supervision	.126
Motor-men and inspectors	1.140
Car cleaners	.120
Fuel	.823
Oil and grease	.044
Accumulators	.021
Sand and various	.083
Car maintenance	.213
Boilers maintenance	.009
Engines maintenance	.032
Dynamos maintenance	.013
Accumulators maintenance	.073
General	.028
Insurance, legal, sinking fund and general	.290
Total expenses	5.001

Table CLXXVII. is interesting as giving the operating expenses of steam, horse, and electric lines run by the same company, and the accounts of which have been kept on the same basis. It must be remarked, however, that in this case the steam line's expenses are given per train mile. These trains are composed of from two to three carriages, but it is not fair to say that a train mileage if run with trains of two cars is equal to double that amount of motor car mileage, the approximate value being more like three trail car to one motor car mile. Taking this basis, it will be found that the steam lines are still much more expensive to work than the electric lines, and this is so much the case that the company who owns these lines is now engaged in transforming most of its existing steam lines into trolley lines. In this case also the tramway company is bound to buy power from the electric lighting station, the latter being the property of the Corporation. The electrical current is generated by turbines directly coupled to the railway generators. The electrical plant was put up at the expense of the Corporation, the specifications, however, being furnished by the tramway company. The electrical power is furnished at the cost of 1.15 pence per Board of Trade unit, the tramway company guaranteeing to

take at least 500,000 units annually. The Corporation have bound themselves to pay the tramway company eightpence for every car-mile which the latter may not be able to run through any fault that can be traced to the Corporation.

TABLE CLXXVII.—Cie. des Tramways Suisses, 1895.

Geneva Steam Tramways, 1895. Expenses per Train-Mile.

	Pence.
Engineer and foreman	0.1536
Mechanics and stokers	1.78176
Lighting, cleaning, greasing and heating	0.67584
Fuel and fodder	2.18112
Maintenance of locomotives	0.79872
" " cars	0.49152
Tools and various expenses	0.12300
Average total pence per train	6.20556

Geneva Horse Tramways. Expenses per Car-Mile.

	Pence.
Engineer and foreman	.07680
Stable attendance	.47584
Drivers	.98304
Lighting, cleaning, greasing and heating	.21504
Food and litter	2.04288
Renewal of horses	4.1472
Shoeing	.16896
Veterinary surgeon	.06144
Harness and accessories	.89968
Maintenance of cars	.23040
Tools and various expenses	.06144
Average total pence per car mile	9.36272
Number of cars	51
Length of track, horse and steam combined	8.63 miles

Geneva Electric Tramways. Per Car-Mile.

	Pence.
Engineer and foreman	.1536
Motor-man	.78336
Lighting, cleaning, greasing and heating	.16396
Motive power	1.96608
Electrical equipment of cars	.47616
Maintenance of cars	.23030
Tools and various expenses	.16896
Average total	3.94742
Length of line	3.38 miles
Number of motor cars	10
Car-miles run	150,000

Table CLXXVIII. gives the average expenditure per train mile on the steam tramways which run throughout the Canton of Geneva.

TABLE CLXXVIII.—AVERAGE EXPENDITURE IN PENCE PER TRAIN-MILE IN 1894 ON THE NARROW GAUGE STEAM RAILWAYS IN THE CANTON OF GENEVA.

Per Train-Mile.

	Pence.
Administration	0.84
Maintenance and repairs of permanent way	1.40
Traffic expenses	2.13
Locomotive management, wages of drivers, stokers, cleaners, &c.	3.2
Fuel, oil, water, sand, &c.	3.52
Repairs and renewals	1.15
Miscellaneous	0.19
Various expenses	1.32
Total pence per train-mile	13.75

Table CLXXIX. gives some interesting data of the Halle electrical tramways, which were amongst the earliest installed on the Continent.

TABLE CLXXIX.—GIVING AVERAGE WORKING EXPENSES IN PENCE PER CAR-MILE FOR THE LAST FOUR YEARS OF HALLE ELECTRIC TRAMWAYS.

	Pence.
Transportation	1.236
Power	0.766
Maintenance of track	0.202
Sinking fund and depreciation	0.774
General expenses	0.578
Total expenses	3.556

Mileage of track	7.88 miles
Number of motor cars in daily operation	28
Total annual car mileage	1,911,900 miles
Maximum gradient	1 : 20
Capital investment per mile of track	£8,250
Ratio of operating expenses to receipts	58 per cent.

The total working cost per car-mile in this case includes taxes, sinking fund, and interest on capital investment.

It must be noted that no conductors are employed, fare-boxes taking their place. This system is worked very successfully on many other roads, the uniform fare being 10 pfennigs, or $1\frac{1}{5}$d.

At Breslau, where electric traction was introduced in June 1893, dividends of 4.7 per cent. were paid the first year, notwithstanding the heavy expenses due to re-equipment, and the shares, issued at 115, are now quoted at over 165. At Erfurt, a dividend of 5 per cent. was paid at the end of the first year's running of its electric lines.

An important fact to be considered is that, owing to the improvement in speed, cleanliness, lighting, heating, ventilation, and general comfort of the passengers, many people travel by electric cars who would never utilise horse cars; increased speed also adds largely to the traffic. American experience has proved that where electricity has taken the place of horse or steam, passenger traffic increases from 30 to 100 per cent. This has also been demonstrated on the Continent. The receipts of the Marseilles tramways, for instance, are:—horses, 13s. 6d.; electric, 28s. 8d. per car.

The hours of running are the same for both systems, but the electric cars run from 25 to 40 miles a day more than the corresponding horse cars. In many parts of the United States cars run 150 to 200 miles a day.

Tables CLXXXI. and CLXXXII., the statistics of which have been got together very carefully, show clearly the enormous progress which has been made of late years on the Continent.

Germany (as shown in Table CLXXX.) is decidedly ahead of any other nation, having four times the electric mileage of England, or nearly more than half the mileage of electric roads constructed all over Europe. In round figures, and allowing for the number of roads equipped since the latest information was received, it may be stated that Europe possesses some 1,300 miles of track equipped electrically, on which are running some 3,000 cars, the power for which is furnished by machinery aggregating nearly 50,000 horse-power. Comparing this to the figures of the United States, we find that the mileage there equipped electrically is more than ten times greater than in Europe.

In round figures the capital invested in electric roads in Germany alone exceeds £5,000,000, and the electrical machinery supplied aggregates some 80,000 kilowatts.

The total street railway mileage of the United States is approximately 6 per cent. of the steam railway mileage. About 6 per cent. of this mileage is in the hands of receivers, against about 25 per cent. of the steam railway mileage. The gross earnings of all American street railway properties are slightly less than 15 per cent. of the combined freight and passenger earnings; but are nearly 50 per cent. of the passenger earnings

alone of the steam railway properties, while the net income applicable to dividends on capital stock is hardly less than 35 per cent. of the steam railway income. That 14,000 miles of street railway track should be able to earn half as much gross on passenger traffic, and one-third as much net (for dividends) on combined passenger and freight traffic, as is earned on 240,000 miles of steam railway track, is certainly a remarkable showing.

TABLE CLXXX.—Giving Resumé of European Electric Lines now Constructed.

Name of Country.	Length of Track in Miles.	Total Number of Electric Cars.	Horse-Power.
Germany	618	1,545	13,810
France	67	180	4,200
Great Britain and Colonies	167	269	9,617
Austria-Hungary	120	265	5,060
Italy	50	149	2,460
Switzerland	30	83	1,570
Belgium	90	157	2,550
Other countries	30	50	1,110
Russia	30	87	1,150
Total	1,202	2,785	41,527

TABLE CLXXXI.—Names of Companies constructing Electric Railroads and Mileage Completed.

	Length of Lines in Miles.
Electric Construction Company, Wolverhampton	52
Mather and Platt, Manchester	32
Siemens Brothers, London	20
Magnus Volk	4
Holroyd Smith	2
The Thomson-Houston System :—	
British Thomson-Houston Co. Cie. Française Thomson-Houston Union Elektricitäts Gesellschaft	652
Crompton and Co.	$1\frac{1}{4}$
The General Traction Co., London	9
British Electric Traction Co.	11
Greenwood and Batley	14
Siemens and Halske	116
Allgemeine Elektricitäts Gesellschaft, Berlin	$157\frac{3}{4}$
Compagnie de l'Industrie Electrique, Geneva	33
Maschinen-Fabrik Oerlikon, Zurich	24
Schuckert, Elektricitäts Actien Gesellschaft	$157\frac{1}{2}$
Ganz and Co., Budapest	$19\frac{1}{2}$
Kummer and Co., Actien Gesellschaft, Dresden	9
Internationale Elektricitäts Gesellschaft, Vienna	$8\frac{1}{2}$

TABLE CLXXXII.—ELECTRIC LINES NOW IN OPERATION IN EUROPE, OR BY EUROPEAN CONSTRUCTORS.

Name of Town.	When Opened.	Track in Miles.	Maximum Grade.	Smallest Radii in Feet.	Gauge of Track.	Number of Motor Cars.	Number of Trailer Cars.	Volts.	Number of Dynamos.	Number of Kilowatts.	Number of Boilers.	Number of Engines.	Indicated Horse-power.	Type of Engine.	How Driven.	System.
LINES CONSTRUCTED BY THE ELECTRIC CONSTRUCTION COMPANY.																
Liverpool	Feb. 1893	32	1 in 33	462	Standard	40	..	500	4	900	6	4	1,600	Horizontal c. condensing	Rope	Third rail
South Staffordshire ..	Dec. 1892	8	1 ,, 40	40	3 ft. 6 in.	16	..	350	3	..	..	3	375	,, ,,	,,	Trolley
Hartlepool	1896	2½	1 ,, 60	40	,, ,,	5	2	500	2	120	..	2	200	Willans' c. non-condensing	Direct-coupled	,,
Madras	1895	9½	1 ,, 40	45	,, ,,	30	..	,,	2	240	..	2	360	Horizontal c. non-c.	Rope	Conduit
LINES CONSTRUCTED BY MESSRS. MATHER AND PLATT.																
Bessbrook—Newry ..	Oct. 1883	3	1 in 50	..	3 ft,	3	..	250	2	72	..	1 turb.	62	Turbines	Belt	Third rail
City of South London	Dec. 1890	5	1 ,, 30	..	Standard	16 Loco.	..	500	4	225	8	4	1,600	Vertical compound	,,	,,
Douglas and Laxey ..	July 1894	14	1 ,, 20	..	Narrow 3 ft.	13	12	,,	3	..	3	3	300	Compound condensing	,,	Trolley
Laxey—Mount Snaefell	Sum. 1895	10	1 ,, 12	660	3 ft. 6 in.	6	..	,,	5	350	4	5	600	Vertical compound	,,	,,
LINES CONSTRUCTED BY THE BRITISH ELECTRIC TRACTION COMPANY, LIMITED.																
North Staffordshire ..	1897	7	..	..	4 ft.	20	20	500	2	400	2	2	700	McIntosh & Seymour	Direct-coupled	Trolley
Hartlepool (Extension)	1897	4	..	..	..	..	..	..	..	..	..	..	..	Vertical	Direct	,,
LINES CONSTRUCTED BY MESSRS. GREENWOOD AND BATLEY COMPANY, LIMITED.																
Leeds	1897	14	1 in 20	..	Standard	25	..	500	4	500	2	2	800	Horizontal compound	Direct coupled	Trolley
LINES CONSTRUCTED BY MESSRS. SIEMENS BROTHERS.																
Guernsey..	March 1892	3	1 in 40	75	4 ft. 8½ in.	10	..	500	2	..	2	2	150	Semi-portable compound	Belt	Trolley
Hobart Town	Sept. 1893	8½	1 ,, 17	70	,, ,,	..	..	,,	2	..	..	2	600	Willans' vertical	Direct	,,
Panama	1893	2	1 ,, 24	45	,, ,,	..	..	440	2	..	..	3	60	..	..	,,
Portrush	Sept. 1883	6	1 ,, 30	..	3 ft.	5	2	250	2	..	..	2	104	Turbines	Belt	Third rail
Ryde Pier	August 1883	1	..	..	4 ft. 8½ in.	2	..	..	..	..	..	..	..	Gas engine	,,	,,
LINES CONSTRUCTED BY MR. MAGNUS VOLK.																
Brighton Beach.. ..	August 1893	1	1 in 14	..	2 ft. 9 in.	3	..	..	1	..	1	1	12 gas	Gas engine	Belt	Third rail
Brighton and Rottingdean Electric Railway	..	3	1 ,, 300	..	2 ft. 8½ in.	2	..	..	2	..	..	1	110	..	..	Trolley

Line Constructed by Mr. Holroyd Smith.

Blackpool	1883	2	1 in 33	62	Standard	10	..	230	4	200	..	2	150	Semi-portable compound	Belt and shaft	Conduit

Line Constructed by Messrs. Crompton and Co.

Southend Pier	August 1890	$1\frac{1}{4}$	6 in.	..	1 ft. 6 in.	3	3	200	2	60	..	2	..	..	Belt	Third rail

Lines Constructed by the General Traction Company, Limited.

Coventry	..	6	..	..	3 ft. 6 in.	10	..	500	2	200	2	2	260	Horizontal	Belt	Trolley
Douglas Southern Tramway	July 1896.	$2\frac{3}{4}$	1 in 16	..	Standard	6	6	,,	2	200	2	2	260	,,	,,	,,

Lines Constructed on the Thomson-Houston System.

(The British Thomson-Houston Company, Limited; Compagnie Française Thomson-Houston; Union Elektricitäts Gesellschaft.)

Bremen	May 1892	10	1 in 50	65	Standard	28	15	500	3	240	3	3	450	Horizontal compound	Belt	Trolley
Remscheid	July 1893	7	1 ,, 16	708	Metre	18	..	,,	4	500	3	4	600	McIntosh & Seymour H.C.	,,	,,
Hamburg	March 1894	180	1 ,, 20	59	Standard	360	300	,,	..	..	..	..	..	Marine Vertical	Direct	,,
Gotha	May 1894	2	1 ,, 25	59	Metre	6	6	,,	..	..	..	..	..	..	..	,,
Erfurt	June 1894	7	1 ,, 13	49	,,	31	17	,,	3	300	3	3	450	Horizontal compound	Belt	,,
Brussels	,, 1894	55	1 ,, 13	65	,,	70	70	,,	9	950	7	9	1,450	McIntosh & Seymour H.C.	Belt and Direct	Trolley (2 miles of conduit)
Milan	Nov. 1893	$4\frac{1}{2}$	1 ,, 25	..	Standard	13	..	,,	2	200	..	2	220	Vertical compound	Belt	Trolley
Munich	Oct. 1895	8	1 ,, 50	45	,,	20	20	,,	..	..	..	..	..	..	..	,,
Elbing	,, 1895	4	1 ,, 25	59	Metre	10	5	,,	2	200	2	2	300	..	..	,,
Dresden	Aug. 1896	..	..	..	Standard	..	..	,,	..	..	..	..	..	..	..	,,
Elberfeld	Jan. 1896	3	1 in 14	49	Metre	12	2	,,	2	200	1	2	300	..	..	,,
Barmen Elberfeld ..	,, 1896	16	..	..	Standard	65	30	,,	..	..	..	..	..	..	..	,,
Leipzig	1896	25	..	49	,,	135	75	,,	4	1,500	6	..	..	..	..	,,
Cairo	Aug. 1896	25	..	..	Metre	40	20	,,	..	..	..	..	..	..	..	,,
Bergen	1896	3	1 in 10	..	,,	12	..	..	..	..	..	..	..	..	..	,,
Berlin	April 1896	17	..	..	Standard	50	50	..	..	..	..	..	..	..	..	Trolley (A few miles of conduit)
Liège	Sept. 1896	10	1 in 30	..	,,	40	40	..	..	..	..	..	..	Vertical	Direct	Trolley
Solingen	Aug. 1896	17	..	..	Metre	30	8	,,	5	500	5	5	750	..	..	,,
Wiesbaden	,, 1896	2	1 in 20	52	,,	7	..	,,	2	200	2	2	300	..	..	,,
Vienna	Nov. 1896	12	..	..	Standard	30	..	..	..	..	..	..	..	..	..	,,
Linz s/ Danube	1896	6	..	..	3 ft.	17	16	,,	5	500	4	4	600	..	..	,,
Lyons	July 1894	13	1 in 14	65	3 ft. 5 in.	23	10	,,	5	475	..	5	670	..	..	,,
Havre	,, 1894	8	1 ,, 18	52	Standard	40	..	,,	3	900	..	3	1,200	McIntosh & Seymour H.C.	Rope	,,
Bordeaux	Dec. 1893	3	1 ,, 50	..	..	8	4	550	2	200	..	2	350	..	..	,,
Oporto	1895	2	1 ,, 10	82	..	3	..	500	1	100	..	1	150	..	..	,,
Florence	Sept. 1890	5	1 ,, 13	59	Standard	10	..	,,	3	240	..	2	270	Vertical compound	Belt	,,
Mussoco	Feb. 1895	4	1 ,, 50	..	,,	6	8	,,	2	200	..	2	300	..	..	,,
Rome	June 1895	5	1 ,, 13	65	,,	14	..	,,	5	440	..	3	500	Turbines	..	,,
Centre (Brussels) ..	1897	$12\frac{1}{2}$	..	..	,,	17	16	600	3	600	6	3	650	..	..	,,
Bristol	Oct. 1895	11	1 in 16	..	,,	22	22	500	4	600	4	4	1,320	McIntosh & Seymour C.	Direct coupled	,,
Dublin	May 1896	8	1 ,, 16	..	5 ft. $2\frac{3}{16}$ in.	20	20	,,	4	..	3	4	600	..	,, ,,	,,
Clontarf (Dublin) ..	1897	6	..	..	,,	15	..	,,	3	450	3	3	990	McIntosh & Seymour C.	,, ,,	,,
Bilbao	1891	9	1 in 15	..	3 ft. 5 in.	12	..	..	2	200	..	2	210	..	..	,,
Roubaix-Tourcoing ..	..	13	1 ,, 33	65	Metre	30	10	500	3	300	..	3	450	..	..	,,
La Raincy	1895	4	1 ,, 25	65	,,	4	..	,,	2	124	..	2	200	..	..	,,
Belgrade	June 1894	$6\frac{1}{4}$	1 ,, 10	82	,,	11	6	,,	2	200	..	2	220	..	..	,,
Varèse	1895	4	1 ,, 15	78	Standard	12	12	..	3	300	..	3	350	..	..	,,

TABLE CLXXXII.—*continued.*

Name of Town.	When Opened.	Track in Miles.	Maximum Grade.	Smallest Radii in Feet.	Gauge of Track.	Number of Motor Cars.	Number of Trailer Cars.	Volts.	Number of Dynamos.	Number of Kilowatts.	Number of Boilers.	Number of Engines.	Indicated Horse-power.	Type of Engine,	How Driven.	System.
Lines Constructed by Messrs. Siemens and Halske.																
Budapest..	July 1889	26	1 in 50	72	Standard	90	10	300	7	700	..	7	1,100	..	Rope and Direct	Trolley and Conduit
Hanover	May 1893	15	1 ,, 25	30	,,	32	18	500	2	300	..	2	400	Horizontal compound	Direct	Trolley
Dresden	July 1893	8	1 ,, 20	42	,,	16	16	,,	2	180	..	2	240	,, ,,	,,	,,
Genoa	May 1893	2	1 ,, 15	82	Metre	4	..	,,	2	220	..	2	240	Vertical	Belt	,,
Barmen Rack Railway..	April 1894	2	1 ,, 5	492	,,	8	..	,,	..	..	..	..	..	..	..	,,
Barmen	Sept. 1894	2	1 ,, 18	72	Standard	7	..	,,	3	400	..	3	600	Horizontal compound	Direct	,,
Mulhouse	July 1894	3	1 ,, 40	49	Metre	9	7	,,	..	..	..	..	..	..	..	,,
Lichterfeld	May 1894	12	1 ,, 23	98	,,	4	..	165	2	44	..	2	60	Vertical and Portable	Belt	,,
Lemberg	,, 1894	20	1 ,, 18	55	,,	16	..	500	4	600	..	4	650	Compound condensing	Direct coupled	,,
Bucharest	Nov. 1894	4	1 ,, 40	45	Standard	15	..	,,	2	100	..	2	150	Compound	Belt and Shaft	,,
Moedling..	Oct. 1883	4	1 ,, 60	98	Metre	8	7	300	3	90	..	4	160	Portable	Belt	,,
Frankfort	April 1884	5	1 ,, 32	98	,,	10	6	,,	4	84	..	4	120	..	..	,,
Serajevo	March 1895	4	1 ,, 33	98	,,	2 Loco.	5	,,	1	70	..	1	75	..	..	,,
Bochum	Dec. 1894	5	1 ,, 54	49	,,	5	4	,,	2	100	..	2	150	..	..	,,
Bâle	May 1895	2	1 ,, 20	49	,,	12	5	500	2	120	..	2	150	..	..	,,
Pankow	March 1895	2	1 ,, 30	82	Standard	8	..	,,	2	120	..	2	150	..	..	,,
Lines Constructed by the Allgemeine Elektricitäts-Gesellschaft Berlin.																
Halle	May 1891	10	1 in 20	49	Metre	36	13	500	4	240	3	2	350	Horizontal	Belt	Trolley
Gera	Feb. 1892	6	1 ,, 20	..	,,	22	16	,,	6	360	3	3	525	Vertical combination	,,	,,
Kiew	May 1892	18	1 ,, 10	..	Standard	46	10	,,	8	480	3	4	700	,, ,,	,,	,,
Breslau	June 1893	10	1 ,, 40	..	,,	55	40	,,	8	480	4	4	720	,, ,,	,,	,,
Essen	Aug. 1893	15	1 ,, 16	..	Metre	24	17	,,	6	360	3	3	540	,, ,,	,,	,,
Chemnitz..	Dec. 1893	14	1 ,, 30	..	3 ft.	44	20	,,	6	360	3	3	460	,, ,,	,,	,,
Christiania	March 1894	4	1 ,, 15	..	Standard	15	7	,,	3	180	3	3	345	,, ,,	,,	,,
Dortmund	April 1894	10	1 ,, 40	..	,,	30	20	,,	4	280	3	3	540	,, ,,	,,	,,
Lubeck	May 1894	8	1 ,, 20	..	,,	28	20	,,	6	360	2	3	540	,, ,,	,,	,,
Plauen	Nov. 1894	3	1 ,, 12	..	Metre	9	..	,,	2	120	2	2	200	,, ,,	,,	,,
Konisberg	Feb. 1895	3	1 ,, 24	..	,,	10	..	,,	1	120	1	1	125	..	..	,,
Eisenach	June 1897	3	1 ,, 19	..	,,	5	4	,,	..	..	..	..	..	..	..	,,
Strasburg	July 1895	3¾	1 ,, 70	..	Standard	14	18	,,	3	..	3	3	300	..	..	,,
Altenburg	April 1895	3	1 ,, 11	..	Metre	7	..	,,	6	216	3	3	330	..	..	,,
Stuttgart..	Sept. 1895	14	1 ,, 17	..	,,	65	50	,,	..	..	..	..	..	..	..	,,
Genoa	Nov. 1895	17¾	1 ,, 12	..	,,	70	10	,,	2	520	4	2	800	..	..	,,
Spandau	Jan. 1896	7	1 ,, 200	..	,,	24	20	,,	2	200	2	2	300	..	..	,,
Bilbao-Santurce	,, 1896	10	1 ,, 20	..	4 ft. 5¾ in.	14	30	,,	3	300	3	3	525	..	..	,,
Danzig	,, 1897	13	1 ,, 30	..	Standard	35	..	,,	6	360	3	3	600	..	..	,,
Nurnberg-Furth ..	1897	25	1 ,, 18	..	,,	68	..	,,	8	380	4	4	700	..	..	,,
Lines Constructed by Messrs. Ganz and Company, Budapest.																
Pressburg	Aug. 1895	2½	1 in 20	80	3 ft. 3 in.	10	5	500	2	132	2	2	170	Steam	..	Trolley
Budapest..	Jan. 1896	7	1 ,, 25	100	4 ft. 6 in.	22	14	400	3	330	3	3	480	,,	..	,,
Miskolcz	March 1897	4	1 ,, 50	80	,,	9	4	500	2	132	2	2	170	..	..	,,
Maros-Szlatina	June 1896	6	1 ,, 17	100	3 ft. 6 in.	1 Loco.	5	,,	1	55	1	1	85	..	..	,,

Lines Constructed by Societé de L'Industrie Electrique, Geneva.

Clermont-Ferrand ..	Oct. 1889	4½	1 in 22	83	Metre	22	..	500	2	165	2	2	500	..	..	Trolley
Stans	Aug. 1893	2	1 ,, 10	164	,,	3	3	,,	2	270	..	2	500	Turbines	Direct	,,
Chavornay	April 1894	2	1 ,, 40	49	Standard	4	..	600	1	150	..	..	..	,,	..	,,
Geneva	Sept. 1894	4	1 ,, 20	82	Metre	10	..	,,	2	60	..	2	70	,,	..	,,
Lyons Ecully	Oct. 1894	2	1 ,, 18	65	,,	5	..	..	1	70	2	1	110	Gas engines	..	,,
Aubonne	March 1896	2	1 ,, 20	131	,,	2	..	500	1	45	..	..	..	..	..	,,
Lausanne..	Sept. 1896	8½	1 ,, 20	59	,,	17	..	,,	2	90	..	..	130	..	..	,,
Steinamauger	1897	1¾	..	..	,,	3	..	..	..	..	..	..	..	..	..	,,
Mont Salève Rack Railway	Aug. 1892	6	1 ,, 4	114	,,	12	..	600	2	330	..	2	500	Turbines	Direct	Rack (third rail)

Lines Constructed by Maschinen-Fabrik Oerlikon, Zurich.

Murren	Aug. 1891	3	1 ,, 20	98	Metre	4	4	600	1	90	..	1 turb.	140	Turbines	..	Trolley
Marseilles	March 1892	8	1 in 18	50	Standard	18	..	550	3	300	..	3	450	Corliss engines	Belt	,,
Sissach Gellerkinden ..	May 1891	2	1 ,, 80	196	Metre	1	4	600	1	35	..	1 turb.	40	Turbines	,,	,,
Zurich Central	Feb. 1895	3	1 ,, 18	49	,,	14	..	550	3	170	..	3	340	Gas engines	,,	,,
Zurich	March 1894	3	1 ,, 18	49	,,	16	..	,,	2	170	..	2	200	,,	,,	,,
Tettnaug	Dec. 1895	3	1 ,, 20	150	,,	2	2	,,	2	90	..	2	240	Steam	,,	,,
Nijni Novgorod.. ..	March 1896	2	1 ,, 20	25	,,	15	..	,,	3	300	..	3	450	,,	,,	,,

Lines Constructed by Messrs. Schuckert, Electricitäts Actien Gesellschaft.

Aix La Chapelle ..	Spring 1895	23½	1 in 15	65	Metre	30	10	500	3	300	..	3	330	Steam	..	Trolley
Augsburg	Autm. 1897	8	1 ,, 15	..	,,	26	..	,,	..	..	..	..	..	..	..	,,
Baden Voslau	July 1894	7	1 ,, 33	65	Standard	25	..	,,	2	350	..	2	700	Steam	..	,,
Czernowitz	Sum. 1897	6	1 ,, 12	..	,,	10	..	,,	..	..	..	..	..	..	..	,,
Dusseldorf	,, 1895	5	1 ,, 50	..	,,	18	..	,,	3	150	..	3	300	..	..	,,
Zwickau	June 1894	5	1 ,, 33	72	Metre	11	..	,,	4	..	..	2	300	..	..	,,
Elberfeld	Sum. 1897	26	1 ,, 17	..	,,	48	..	,,	..	..	..	..	..	..	..	,,
Altona (Hamburg) ..	,, 1897	20	1 ,, 20	..	Standard	80	..	,,	..	..	..	..	..	Vertical steam	Direct	,,
Jekatrinoslaw	,, 1897	10	1 ,, 13	..	Metre	26	..	,,	..	..	..	..	..	..	..	,,
Krakau	,, 1897	2½	1 ,, 33	..	,,	12	..	,,	..	..	..	..	..	..	..	,,
St. Moritz	Spring 1895	1	1 ,, 17	..	,,	4	..	,,	..	..	..	..	..	..	..	,,
Munich	,, 1895	2	1 ,, 25	..	Standard	8	..	600	..	..	..	..	..	..	..	,,
Palermo		10	1 ,, 40	..	Metre	26	..	500	..	..	..	..	..	..	..	,,
Reichenberg	Sum. 1897	4½	1 ,, 13	..	,,	8	..	,,	..	..	..	..	..	..	..	,,
Schwabing	,, 1897	1	..	..	Standard	2	..	150	..	..	..	..	..	..	..	,,
Toulon	Spring 1897	10	..	..	,,	30	..	500	..	..	..	..	..	..	..	,,
Turin		3	..	..	Metre	7	..	,,	..	..	..	..	..	..	..	,,
Ulm	Autm. 1896	5	..	..	,,	8	..	,,	..	..	..	..	..	..	..	,,
Vohwinkel	,, 1897	8	1 ,, 10	..	,,	34	..	,,	..	..	..	..	..	..	..	,,

Lines Constructed by Messrs. Kummer and Company, Actien Gesellschaft, Dresden.

Blasewitz..	Oct. 1893	3	1 in 33	39	3 ft. 3½ in.	9	9	500	2	258	..	4	340	Steam	..	Trolley
Vevey Montreux ..	1888	6	1 ,, 33	131	Standard	19	..	600	2	568	..	2	Turb.	Turbines	..	,,

Lines Constructed by Internationale Elektricitäts Gesellschaft, Vienna.

Teplitz, Ecchwald ..	July 1895	5¼	1 in 18	120	Metre	8	6	500	3	200	2	3	540	..	..	..
Bielitz, Liegeunerwald	Oct. 1895	3¼	..	..	,,	6	2	,,	1	100	2	1	180	..	..	..

Table CLXXXIII. gives an interesting comparison between the capital expenditure of receipts, mileage, and traffic of the English and American railways and tramways. From this Table we see that, whilst the capital expenditure per mile of railway in America is less than a quarter of that of English railways, the capital invested per mile of tramway in England is practically double that invested in America, notwithstanding the improved methods of traction introduced there. The particular point, however, to which attention is drawn, is the fact that the number of passengers carried in America during the year is approximately six times that carried by all the American railroads, whereas in England, the tramways only carry slightly more than half the number of the passengers carried by the railways; and also that whilst we have succeeded in running the railways more economically than in the United States, the reverse is the case with the tramways.

TABLE CLXXXIII.—Giving Approximate Comparison between Railways and Tramways in England and America.

Items.	America.		United Kingdom.	
	Railways.	Tramways.	Railways.	Tramways.
Capital expenditure	£2,334,200,000	£280,000,000	£880,000,000	£13,000,000
Total mileage	240,000 miles	14,000 miles	20,000 miles	1,000 miles
Gross receipts	£219,000,000	£32,850,000	£77,025,000	£3,540,000
Total expenses	£154,000,000	£22,700,000	£40,100,000	£2,640,000
Passengers carried	544,000,000	3,000,000,000	775,200,000	480,000,000
Ratio of expenses to receipts	67.5 per cent.	approx. 65 per cent.	52 per cent.	75 per cent.

APPENDIX.

BOARD OF TRADE REGULATIONS.

REGULATIONS prescribed by the Board of Trade under the provisions of Section ...... of the .... Tramways Act, 189..., for regulating the employment of insulated returns, or of uninsulated metallic returns of low resistance; for preventing fusion or injurious electrolytic action of or on gas or water pipes or other metallic pipes, structures, or substances; and for minimising, as far as is reasonably practicable, injurious interference with the electric wires, lines, and apparatus of parties other than the company, and the currents therein, whether such lines do or do not use the earth as a return.

DEFINITIONS.

In the following regulations:—

The expression "energy" means electrical energy.

The expression "generator" means the dynamo or dynamos or other electrical apparatus used for the generation of energy.

The expression "motor" means any electric motor carried on a car and used for the conversion of energy.

The expression "pipe" means any gas or water pipe or other metallic pipe, structure, or substance.

The expression "wire" means any wire or apparatus used for telegraphic, telephonic, electrical signalling, or other similar purposes.

The expression "current" means an electric current exceeding one-thousandth part of one ampere.

The expression "the company" has the same meaning or meanings as in the .... Tramways Act, 189....

REGULATIONS.

1. Any dynamo used as a generator shall be of such pattern and construction as to be capable of producing a continuous current without appreciable pulsation.

2. One of the two conductors used for transmitting energy from the generator to the motors shall be in every case insulated from earth, and is hereinafter referred to as the "line"; the other may be insulated throughout, or may be uninsulated in such parts and to such extent as is provided in the following regulations, and is hereinafter referred to as the "return."

3. Where any rails on which cars run or any conductors laid between or within three feet of such rails form any part of a return, such part may be uninsulated. All other returns or parts of a return shall be insulated, unless of such sectional area as will reduce the difference of potential between the ends of the uninsulated portion of the return below the limit laid down in Regulation 7.

4. When any uninsulated conductor laid between or within three feet of the rails forms any part of a return, it shall be electrically connected to the rails at distances apart not

exceeding 100 feet, by means of copper strips having a sectional area of at least one-sixteenth of a square inch, or by other means of equal conductivity.

5. When any part of a return is uninsulated it shall be connected with the negative terminal of the generator, and in such case the negative terminal of the generator shall also be directly connected, through the current-indicator hereinafter mentioned, to two separate earth connections, which shall be placed not less than twenty yards apart.

Provided that in place of such two earth connections the company may make one connection to a main for water-supply of not less than three inches internal diameter, with the consent of the owner thereof and of the person supplying the water; and provided that where, from the nature of the soil or for other reasons, the company can show to the satisfaction of an inspecting officer of the Board of Trade that the earth connections herein specified cannot be constructed and maintained without undue expense, the provisions of this regulation shall not apply.

The earth connections referred to in this regulation shall be constructed, laid, and maintained so as to secure electrical contact with the general mass of earth, and so that an electromotive force not exceeding four volts shall suffice to produce a current of at least two amperes from one earth connection to the other through the earth, and a test shall be made at least once in every month to ascertain whether this requirement is complied with.

No portion of either earth connection shall be placed within six feet of any pipe, except a main for water supply of not less than three inches internal diameter, which is metallically connected to the earth connections with the consents hereinbefore specified.

6. When the return is partly or entirely uninsulated the company shall, in the construction and maintenance of the tramway—(*a*), so separate the uninsulated return from the general mass of earth, and from any pipe in the vicinity; (*b*) so connect together the several lengths of the rails; (*c*) adopt such means for reducing the difference produced by the current between the potential of the uninsulated return at any one point and the potential of the uninsulated return at any other point; and (*d*) so maintain the efficiency of the earth connections specified in the preceding regulations as to fulfil the following conditions, viz.:—

(i.) That the current passing from the earth connections through the indicator to the generator shall not at any time exceed either two amperes per mile of single tramway line or 5 per cent. of the total current output of the station.

(ii.) That if at any time and at any place a test be made by connecting a galvanometer or other current indicator to the uninsulated return and to any pipe in the vicinity, it shall always be possible to reverse the direction of any current indicated by interposing a battery of three Leclanche cells connected in series if the direction of the current is from the return to the pipe, or by interposing one Leclanche cell if the direction of the current is from the pipe to the return.

In order to provide a continuous indication that the condition (i.) is complied with, the company shall place in a conspicuous position a suitable, properly connected, and correctly marked current-indicator, and shall keep it connected during the whole time that the line is charged.

The owner of any such pipe may require the company to permit him at reasonable times and intervals to ascertain by test that the conditions specified in (ii.) are complied with as regards his pipe.

7. When the return is partly or entirely uninsulated, a continuous record shall be kept by the company of the difference of potential during the working of the tramway between the points of the uninsulated return furthest from and nearest to the generating station. If at

any time such difference of potential exceeds the limit of seven volts, the company shall take immediate steps to reduce it below that limit.

8. Every electrical connection with any pipe shall be so arranged as to admit of easy examination, and shall be tested by the company at least once in every three months.

9. Every line and every insulated return or part of a return, except any feeder, shall be constructed in sections not exceeding one half of a mile in length, and means shall be provided for insulating each such section for purposes of testing.

10. The insulation of the line and of the return when insulated, and of all feeders and other conductors, shall be so maintained that the leakage current shall not exceed one-hundredth of an ampere per mile of tramway. The leakage current shall be ascertained daily before or after the hours of running, when the line is fully charged. If at any time it should be found that the leakage current exceeds one-half of an ampere per mile of tramway, the leak shall be localised and removed as soon as practicable, and the running of the cars shall be stopped unless the leak is localised and removed within 24 hours. Provided that where both line and return are placed within a conduit this regulation shall not apply.

11. The insulation resistance of all continuously insulated cables used for lines, for insulated returns, for feeders, or for other purposes, and laid below the surface of the ground, shall not be permitted to fall below the equivalent of 10 megohms for a length of one mile. A test of the insulation resistance of all such cables shall be made at least once in each month.

12. Where in any case in any part of the tramway the line is erected overhead and the return is laid on or under the ground, and where any wires have been erected or laid before the construction of the tramway in the same or nearly the same direction as such part of the tramway, the company shall, if required so to do by the owners of such wires or any of them, permit such owners to insert and maintain in the company's line one or more induction coils or other apparatus approved by the company for the purpose of preventing disturbance by electric induction. In any case in which the company withhold their approval of any such apparatus the owners may appeal to the Board of Trade, who may, if they think fit, dispense with such approval.

13. Any insulated return shall be placed parallel to and at a distance not exceeding three feet from the line when the line and return are both erected overhead, or 18 inches when they are both laid underground.

14. In the disposition, connections, and working of feeders the company shall take all reasonable precautions to avoid injurious interference with any existing wires.

15. The company shall so construct and maintain their system as to secure good contact between the motors and the line and return respectively.

16. The company shall adopt the best means available to prevent the occurrence of undue sparking at the rubbing or rolling contacts in any place, and in the construction and use of their generator and motors.

17. In working the cars the current shall be varied as required by means of a rheostat containing at least twenty sections, or by some other equally efficient method of gradually varying resistance.

18. Where the line or return or both are laid in a conduit, the following conditions shall be complied with in the construction and maintenance of such conduit :—

(*a*) The conduit shall be so constructed as to admit of easy examination of and access to the conductors contained therein and their insulators and supports.

(*b*) It shall be so constructed as to be readily cleared of accumulation of dust or other *débris*, and no such accumulation shall be permitted to remain

(*c*) It shall be laid to such falls, and so connected to sumps or other means of drainage, as to automatically clear itself of water without danger of the water reaching the level of the conductors.

(*d*) If the conduit is formed of metal, all separate lengths shall be so jointed as to secure efficient metallic continuity for the passage of electric currents. Where the rails are used to form any part of the return, they shall be electrically connected to the conduit by means of copper strips having a sectional area of at least one-sixteenth of a square inch, or other means of equal conductivity, at distances apart not exceeding 100 feet. Where the return is wholly insulated and contained within the conduit, the latter shall be connected to earth at the generating station through a high resistance galvanometer, suitable for the indication of any contact or partial contact of either the line or the return with the conduit.

(*e*) If the conduit is formed of any non-metallic material not being of high insulating quality and impervious to moisture throughout, and is placed within six feet of any pipe, a non-conducting screen shall be interposed between the conduit and the pipe, of such material and dimensions as shall provide that no current can pass between them without traversing at least six feet of earth; or the circuit itself shall in such case be lined with bitumen or other non-conducting damp-resisting material in all cases where it is placed within six feet of any pipe.

(*f*) The leakage current shall be ascertained daily, before or after the hours of running, when the line is fully charged, and if at any time it shall be found to exceed half an ampere per mile of tramway the leak shall be localised and removed as soon as practicable, and the running of the cars shall be stopped unless the leak is localised and removed within 24 hours.

19. The Company shall, so far as may be applicable to their system of working, keep records as specified below. These records shall, if and when required, be forwarded for the information of the Board of Trade.

DAILY RECORDS.

Number of cars running.
Maximum working current.
Maximum working pressure.
Maximum current from the earth connections (*vide* Regulation 6 (i.)).
Leakage current (*vide* Regulations 10 and 18 (*f*)).
Fall of potential in return (*vide* Regulation 7).

MONTHLY RECORDS.

Condition of earth connections (*vide* Regulation 5).
Insulation resistance of insulated cables (*vide* Regulation 11).

QUARTERLY RECORDS.

Conductance of joints to pipes (*vide* Regulation 8).

OCCASIONAL RECORDS.

Any tests made under provisions of Regulation 6 (ii.).
Localisation and removal of leakage, stating time occupied.
Particulars of any abnormal occurrence affecting the electric working of the tramway.

Signed by order of the Board of Trade this ...... day of ...., 189....

———————————,

Assistant Secretary, Board of Trade.

STATUTORY RULES AND ORDERS, 1895.—No. 160.

TRAMWAY AND LIGHT RAILWAY, IRELAND.

The Dublin United Tramways Company Construction and Diversions Order, 1895. (Dated March 28, 1895.)

By the Lords Justices and Privy Council in Ireland.

S. Walker, C.
Wolseley, F.M.

Whereas the grand jury of the county of Dublin, on the 17th day of April, 1894, and the lord mayor, aldermen, and burgesses of the city of Dublin, at the Easter Sittings, 1894, acting in execution of the powers vested in them by the Tramways (Ireland) Act, 1860, and the Tramways (Ireland) Amendment Act, 1861, and the Tramways (Ireland) Acts Amendment (Dublin) Act, 1876, passed resolutions definitely approving of the Dublin United Tramways Company junctions and extensions tramways in the said county of Dublin and city of Dublin, which are specified in the schedule hereto, so far as same are to be constructed within their jurisdiction:

And whereas, on the 19th day of December, 1894, the Dublin United Tramways Company, being the promoters of said undertaking, presented a memorial to the Lord Lieutenant in Council, praying for an Order to authorise the construction of the tramways mentioned in such memorial and confirm the said resolutions; and it appears to the Lord Lieutenant in Council expedient to make the order following:—

Therefore it is ordered by the Lords Justices General and General Governors of Ireland, by and with the advice of Her Majesty's Privy Council in Ireland:

Promoters.

1. The Dublin United Tramways Company shall be the promoters for the purpose of this Order, and the said Company and their assigns are in this Order referred to as "the promoters."

Power to Construct Line.

2. The promoters may construct, maintain, equip, and work, subject to the provisions of this Order and of the Acts incorporated herewith, the tramways described in the schedule to this Order, in the directions and levels, with the powers of deviation (if any) specified and described in the plans, books of reference, and sections, deposited by the promoters with the secretary of the grand jury of the county of Dublin, and with the town clerk of the Dublin Municipal Corporation, and herein-after described as the deposited plans, sections, and book of reference, with all necessary and proper rails, plates, sleepers, works, sidings, and conveniences connected therewith, and for the purposes thereof (subject to the provisions of the said Acts).

Gauge and other Particulars.

3. The gauge of the tramways shall be 5 ft. 3 in.

Time for Completion.

4. The promoters shall complete and finish ready for use the said tramways, and shall provide a proper quantity of rolling stock within *five* years from the date of this Order becoming binding.

Power to Cross Roads.

5. The promoters may, subject to the provisions of the Acts incorporated herewith and of this Order, for the purpose of the said tramways and construction thereof, cross, alter, or

divert, temporarily or permanently, any roads, streets, highways, streams, sewers, pipes, or other works.

NOTICE TO SURVEYOR AND CITY ENGINEER.

6. Before the promoters commence to open or break up a street or high road, they shall give to the county surveyor, or to the engineer of the city of Dublin, as the case may be, notice of their intention to do so, such notice to be given 48 hours before the commencement of the work.

SUPERINTENDENCE BY COUNTY SURVEYOR AND CITY ENGINEER.

7. They shall not open or break up any street or road along which the tramway is to be laid, save and except with the approval and under the superintendence of the county surveyor, or the engineer for the Dublin Municipal Corporation, unless he neglects or refuses to give such superintendence at the time specified in the notice of the promoters, or discontinues the same during the work. The county surveyor and the said engineer for the Dublin Municipal Corporation shall be paid by the promoters such reasonable renumeration for the duties hereby imposed upon them as may be directed by the Lord Lieutenant, by any general or special order.

RESTORING ROADS.

8. The promoters shall, after having opened or broken up a street or high road, with all convenient speed complete the work on account of which they opened or broke up the same (subject to the formation of the said tramway), fill in the ground level, and make good the surface and generally restore the street or high road to as good a condition as that in which it was before it was opened or broken up, and clear away all rubbish occasioned thereby. They shall during such period as the street or as the high road may be opened or broken up, cause the place where the street or high road is opened or broken up to be fenced and watched, and to be properly lighted at night.

ALTERATION OF LEVEL OF ROADS.

9. If any authority having the control of any road or street along or across which any of the tramway authorised by this Order is laid, hereafter alter the level of such road or street, the promoters shall from time to time alter their rails, and lay them so that they shall not be a danger or annoyance to the ordinary traffic in the road or street.

EXPENSES OF REPAIRS.

10. The promoters shall pay all reasonable expenses of the repairs of the streets and high road upon which they shall have constructed any part of the said tramway, for six months after the same shall have been restored, so far as those expenses are increased by the opening or breaking up of the street or road.

MAINTENANCE OF SIDINGS AND RAILS.

11. The promoters shall, at their own expense, maintain and repair all sidings on which any tramway shall be laid.

POWER TO ENFORCE OBLIGATIONS OF PROMOTERS.

12. In case the promoters shall at any time fail or neglect to carry out any work of maintenance or repair imposed upon them by this Order, after the expiration of four days from the service on them of a notice in writing by the county surveyor, or his assistants, or by the engineer for the Dublin Municipal Corporation, it shall be lawful for any two magistrates of the county, or one of the divisional magistrates of the Dublin Metropolitan District,

without prejudice to any other remedy in that behalf, to order any work for maintenance or repair as aforesaid, to be executed by the promoters at their own expense, within such time as the said magistrates shall direct; and in default thereof it shall be lawful for the county surveyor, or for the engineer of the Dublin Municipal Corporation, to cause said work to be executed, and the promoters shall, on demand by the county surveyor or the city engineer, pay to him all expenses incurred in the execution thereof.

The Company shall, at their own expense, at all times, maintain and keep in good condition and repair, and as to any particular street, road, or part of a street or road, if required by the road authority so to do, pave and keep paved with such materials and in such manner as the road authority shall direct, and to their satisfaction, so much of any street or road wherever any tramway of the Company is laid, as lies between the rails of the tramway, and where two tramways of the company are laid in any street or road the portion of the road between the tramways, and in any case so much of the road as extends 18 in. beyond the rails, of and on either side of, any tramway of the Company. If the Company abandon their undertaking, or any part of the same, and take up any tramway or part of any tramway belonging to them, they shall with all convenient speed, and in all cases within six weeks at the most, unless the road authority otherwise consent in writing, fill in the ground and make good the surface, to the satisfaction of the county surveyor and the city engineer, or restore the portion of such street or road upon which such tramway was laid to as good condition as that in which it was before the tramway was laid thereon, and clear away all surplus paving or metalling material, or rubbish occasioned by such work, and they shall in the meantime cause the place where the street or road is opened or broken up to be fenced and watched, and to be properly lighted at night. Provided always that if the Company fail to comply with the provisions of this section, the road authority, if they think fit, may themselves, at any time after seven days' notice to the Company, open and break up the road and do the works necessary for the repairs and maintenance or restoration of the road to the extent in this section mentioned, and the expense incurred by the road authority in so doing shall be repaid to them by the Company.

The promoters shall lay down wood pavement for the full width of the intended lines, and 18 in. on either side thereof, before the Presbyterian Church at Donore Terrace, and before the new Catholic Chnrch at Dolphin's Barn, and for a certain distance on either side of them, as shall be pointed out by the borough surveyor, whenever the corporation call on them to do so.

With respect to Tramway No. 2, the promoters shall lay down both lines for the entire width, and 18 in. on either side thereof in wood, and maintain them in the ordinary way for the entire length which the corporation have laid down with wood opposite the Mater Misericordiæ Hospital, and St. Joseph's Church, Berkeley Road.

With respect to Tramway No. 3, the promoters shall lay down wood pavement for the width of their entire lines and 18 in. on either side opposite Phibsborough Catholic Church, and the Female Orphanage Church on the North Circular Road, whenever the corporation call upon the company to do so, and all such pavements shall be made and maintained by the Company with good materials, and from time to time when necessary repaired, and shall be so maintained and repaired to the satisfaction of the city engineer.

The promoters shall, in making the alterations in their lines in South Great George's Street, so construct the lines that in relaying them the space between the outside edge of the tram rail nearest the kerbstone on Pim Bros. (Limited) side of the street shall not be less than 8 ft. opposite the houses numbered 7, 8, and 9, measured from the middle of No. 7 to the middle of No. 9, and not less than 8 ft. 3 in. opposite the houses numbered 10, 11, and 12, measured from the middle of No. 10 to the middle of No. 12.

RIGHT AS TO ROADS.

13. The promoters shall not be deemed to acquire any right other than that of user only in the soil of any street or high road along or across which they may lay any tramway.

In the construction of the tramways authorised by this Order, as set forth in the schedule hereto, in paved streets where the cross section is already heavy, the promoters shall lower and alter their lines and paving and properly bond their paving in with the corporation paving adjoining, so as to bring the thoroughfare to a proper cross section to the satisfaction of the city engineer; and the promoters shall lay the said lines so authorised in macadamized streets at such a level that the cross section will suit for paved streets, and if this is not done the promoters shall be bound at any time afterwards, upon being required to do so (by the authority having the control of said street), to alter the levels, not only of the rails but of the entire tramway paving, to suit the level at which it may be found necessary that such streets should be paved by the corporation, and in all cases the entire paving shall be according to the requirements of the corporation, and laid in a bed of concrete not less than 6 in. deep, with tarred joints, which are not to be of a greater width than $\frac{1}{2}$ in. for stone and $\frac{1}{4}$ in. for wood, and shall properly bond into the adjoining paving of the corporation in paved streets to the satisfaction of the city engineer. If it is found necessary for the corporation to repair, macadamize, or alter the levels of any portion of the adjoining street or thoroughfare in consequence of the tramway rails or paving to be laid under this Order, the corporation shall be reimbursed or paid the full costs of such work by the promoters.

ADDITIONAL POWERS AS TO CROSSINGS AND WORKS.

14. The promoters may, with the consent of the corporation and county grand jury, and to the satisfaction of their engineers, subject to the provisions of this Order, from time to time make all such crossings, passing places, sidings, junctions, and other works in addition to those particularly mentioned in the said deposited plans and sections, as may from time to time be necessary or convenient for the efficient working of the said tramways, or for providing access to any stables, carriage-houses, engine-houses, warehouses, or works of the promoters.

TEMPORARY WORKS.

15. If and whenever it shall become necessary for the purpose of repair, or other similar or temporary purposes, to remove or close any part of the said tramway of the promoters, they may lay down and maintain for the time necessary, but no longer, on some other part of the same tramway, or on an adjoining part of the road, a temporary tramway instead of the part removed or closed, and may maintain and use the same until the part so removed or closed is reinstated, subject to the approval of the city engineer or county surveyor, and with his consent and knowledge.

TOLLS.

16. The promoters shall be entitled to demand and take such tolls and charges as shall not exceed the maximum tolls and rates of charges which are specified in the schedule to the Tramways (Ireland) Act, 1860, or any amendment thereof.

LIST OF TOLLS.

17. A list of all the tolls and charges authorised to be taken shall be exhibited in a conspicuous place inside and outside each of the carriages used upon the said tramways.

FORM OF RAIL.

18. The form of rail shall be approved by the said county surveyor and by the engineer for the Dublin Municipal Corporation; but in the event of the promoters being dissatisfied

with their decision, or that of either of them, they shall be at liberty to appeal to the Board of Trade, whose decision shall be final.

MOTIVE POWER.

19. The carriages used on the said tramways shall, subject to the provisions of this Order, be moved by animal power only.

COSTS OF ORDER.

20. The costs, charges, and expenses of obtaining this Order, or otherwise in relation thereto, including the expenses incurred by the grand jury of the county of Dublin, and by the municipal corporation of the city of Dublin, in relation thereto, shall be paid by the promoters.

PROVISIONS FOR SECURING THE COMPLETION AND MAINTENANCE OF THE TRAMWAYS.

21. The promotors shall complete the undertaking within the time limited by this Order, and shall at all times efficiently work the undertaking, and shall at all times maintain and keep in good condition and repair, and so as not to be a danger or annoyance to the ordinary traffic, the rails and paving of which any of the tramways for the time being consist, and the substructure upon which the same rest, to the satisfaction of the city engineer.

CARRYING OF MAILS BY COMPANY.

22.—(1) The promoters, if required by the Postmaster-General, shall perform with respect to any tramway owned or worked by them, all such reasonable services in regard to the conveyance of mails as Her Majesty's Postmaster-General from time to time requires, provided as follows :—

(*a*) Nothing in this section shall authorise the Postmaster-General to require mails in excess of the following weights to be carried by the Company in or upon any carriage, that is to say,—

(i) If the carriage is conveying or intended to convey passengers and not goods or parcels, then in excess of the maximum weight for the time being fixed for the luggage of ordinary passengers ; and

(ii) If the carriage is conveying or intended to convey parcels only, then in excess of such maximum weight as is for the time being fixed for ordinary parcels; or if that maximum appears to the Postmaster-General to be so slow as to exclude him from availing himself of the use of any such carriage, then as is for the time being fixed by agreement, or in default of agreement by a referee to be appointed at the request of either party by the Lord Chancellor of Ireland ; and

(iii) If the carriage is conveying or intended to convey both parcels and passengers but not goods, then in excess of the maximum weight for the time being fixed for ordinary parcels or for the luggage of ordinary passengers, whichever is the greater.

(*b*) Mails, when carried in or upon a carriage conveying passengers, shall be so carried as not to inconvenience the passengers, but so nevertheless that the custody of the mails by any officer of the Post Office in charge thereof shall not be interfered with.

(*c*) Nothing in this section shall authorise the Postmaster-General to require any mails to be carried by the Company in or upon a carriage conveying or intended to convey passengers but not goods or parcels, except in charge of an officer of the Post Office travelling as a passenger.

(*d*) If the promoters carry goods as well as passengers and parcels, the enactments relating to the conveyance of mails by railway shall, subject to the provisions of this section, apply in like manner as if the promoters were a railway company, and the tramway were a railway.

(2) The remuneration for any serviccs which have been performed by the promoters in pursuance of this section shall be such as may be from time to time determined by agreement between Her Majesty's Postmaster-General and the promoters, or, in defalt of agreement, by a referee to be appointed by the Lord Chancellor of Ireland at the request of either party, and this provision shall have effect in lieu of any provisions respecting remuneration contained in the enactments relating to the conveyance of mails by railway which are applied by this section.

36 and 37 Vict. c. 48; 45 and 46 Vict. c. 74.

(3) For the purposes of this section, the expression "mails" has the same meaning as in the Regulation of Railways Act, 1873, and includes parcels within the meaning of the Post Office (Parcels) Act, 1882.

(4) For the purposes of this section, a requisition by Her Majesty's Postmaster-General may be signified by writing under the hand of any person who is at the time either such Postmaster-General or a Secretary or Assistant-Secretary of the Post-Office, or the Inspector-General of Mails; and any document purporting to be signed by any such person as aforesaid shall, until the contrary is proved, be deemed, without proof of the official character of such person, to have been duly signed as required by this section.

Provision for Protection of the Postmaster-General.

23. In the event of any of the tramways of the promoters being worked by electricity, the following provisions shall have effect :—

(1) The promoters shall construct their electric lines and other works of all descriptions, and shall work their undertaking in all respects with due regard to the telegraphic lines from time to time used or intended to be used by Her Majesty's Postmaster-General, and the currents in such telegraphic lines, and shall use every reasonable means in the construction of their electric lines and other works of all descriptions, and the working of their undertaking, to prevent injurious affection, whether by induction or otherwise, to such telegraphic lines, or the currents therein. If any question arises as to whether the promoters have constructed their electric lines or other works, or work their undertaking in contravention of this sub-section, such question shall be determined by arbitration, and the promoters shall be bound to make any alterations in or additions to their system which may be directed by the arbitrator.

(2)—(*a*) Before any electric line is laid down or any act or work for working the tramways by electricity is done within 10 yards of any part of a telegraphic line of the Postmaster-General (other than repairs, or the laying of lines crossing the line of the Postmaster-General at right angles at the point of shortest distance, and so continuing for a distance of 6 feet on each side of such point), the promoters or their agents not more than 28 or less than 14 days before commencing the work shall give written notice to the Postmaster-General specifying the course of the line and the nature of the work, including the gauge of any wire, and the promoters and their agents shall conform with such reasonable requirements (either general or special) as may from time to time be made by the Postmaster-General for the purpose of preventing any telegraphic line of the Postmaster-General from being injuriously affected by the said act or work.

(*b*) Any difference which arises between the Postmaster-General and the promoters or their agents with respect to any requirements so made shall be determined by arbitration.

(3) In the event of any contravention of or wilful non-compliance with this section by the promoters or their agents, the promoters shall be liable to a fine not exceeding £10 for every day during which such contravention or non-compliance continues, or if the telegraphic communication is wilfully interrupted, not exceeding £50 for every day on which such interruption continues.

(4) Provided that nothing in this section shall subject the promoters or their agents to a fine under this section if they satisfy the Court having cognizance of the case that the immediate doing of the act or execution of the work was required to avoid an accident, or otherwise was a work of emergency, and that they forthwith served on the postmaster or sub-postmaster of the postal telegraph office nearest to the place where the act or work was done a notice of the execution thereof, stating the reason for doing or executing the same without previous notice.

(5) For the purpose of this section a telegraphic line of the Postmaster-General shall be deemed to be injuriously affected by an act or work if the telegraphic communication by means of such line is, whether through induction or otherwise, in any manner affected by such act or work, or by any use made of such work.

41 AND 42 VICT., C. 76.

(6) For the purposes of this section, and subject as therein provided, sections 2, 8, 9, 10, 11, and 12 of the Telegraph Act, 1878, shall be deemed to be incorporated with this Order, as if the promoters were undertakers within the meaning of those sections, without prejudice nevertheless to any operation which the other sections of the said Act would have had if this section had not been enacted, and in particular, nothing in this section shall be deemed to exclude the provisions of section 7 of the Telegraph Act, 1878, in relation to the matters mentioned in that section.

(7) The expression "electric line" has the same meaning in this section as in the Electric Lighting Act, 1882.

31 AND 32 VICT., C. 119.

(8) Any question or difference arising under this section which is directed to be determined by arbitration shall be determined by an arbitrator appointed by the Board of Trade on the application of either party, whose decision shall be final, and sections 30 to 32, both inclusive, of the Regulation of Railways Act, 1868, shall apply in like manner as if the promoters or their agents were a company within the meaning of that Act.

(9) Nothing in this section contained shall be held to deprive the Postmaster-General of any existing right to proceed against the promoters by indictment, action, or otherwise, in relation to any of the matters aforesaid.

INQUIRY AS TO DEFAULT IN COMPLETION OF MAINTENANCE.

24. In any case in which it is represented in writing to the Board of Trade by the grand jury of the county of Dublin, or by the Dublin Municipal Corporation, or by twenty ratepayers of the said county or city, or by the county surveyor of the said county, or the engineer of the said city, that the promoters have made any default in the completion, working, or maintaining of the line, the Board of Trade may, if they think fit, direct an inquiry by an officer to be appointed by the said Board, such inquiry to be conducted in such manner as the

Board of Trade may order, and if the Board of Trade certify that the default mentioned in such representation has been proved to the satisfaction of the said Board, the promoters shall make good such default in the manner and within the time specified in such certificate.

INCORPORATION OF ACTS.

25. The Tramways (Ireland) Acts and the following Acts (so far as they are not inconsistent with the aforesaid Acts and this Order), and subject to the modifications in the said Tramways Acts contained, that is to say:—The Lands Clauses Acts, and the Dublin Tramways Acts, 1871, 1873, and 1878; the North Dublin Street Tramways Acts, 1875, 1876, and 1880; and the Dublin United Tramways Companies Act, 1881; the Tramways (Ireland) Act, 1860; the Tramways Amendment Acts, 1861, 1871; the Companies Clauses Acts, 1845, 1863, and 1869; the Railway Clauses Acts, 1845 and 1863; and the Regulation of Railways Act, 1868, and so far as the same may be necessary for the purpose of the Order, shall be incorporated with this Order, except where the same are expressly varied by this Order.

INTERPRETATION.

26. In this Order the several words, terms, and expressions to which meanings are assigned by the Tramways (Ireland) Acts have the same meanings respectively.

Provided that in this Order the expressions "tramways" and the "undertaking" shall mean respectively the tramways and works, and the undertaking authorised by this Order. The expression "county surveyor" and "engineer" shall include the county surveyor for the time being of the county of Dublin, and the engineer for the time being of the municipal corporation of the city of Dublin. The expression "grand jury" shall mean the grand jury of the county of Dublin, and the expression "municipal corporation" shall mean the corporation of the city of Dnblin.

Provided also that in this Order the term "the Tramways (Ireland) Acts" means the Tramways (Ireland) Act, 1860, and the Tramways (Ireland) Amendment Act, 1861.

SHORT TITLE.

27. This Order may be cited for all purposes as "thc Dublin United Tramways Company Construction and Diversions Order, 1861."

Given at the Council Chamber, Dublin Castle, the 28th day of March, 1895.

MACDERMOT.
JOSEPH M. MEADE.

SCHEDULE REFERRED TO IN FOREGOING ORDER, BEING A DESCRIPTION OF THE PROPOSED WORKS.

Tramway No. 1.—59 chains in length or thereabouts, a double line, situate partly in the parishes of St. Catherine's and St. James's, in the city and county of Dublin, commencing with junctions to the existing lines of tramways at the corner of Clanbrassil Street and South Circular Road, passing from thence in a westerly direction along the South Circular Road, and terminating in Dolphin's Barn, at a point 190 feet distant or thereabouts from the north-east corner of the Dolphin's Barn Roman Catholic Church.

Tramway No. 2.—30 chains in length or thereabouts, a double line, situate in the parish of St. George, in the city of Dublin, commencing with junctions to the existing tramway at the corner of Blessington Street and Berkeley Street, passing along Berkeley Street in a northerly direction, and westerly direction along the North Circular Road, terminating with junctions to the east end of the existing lines of tramways in Madras Place.

Tramway No. 3.—99.5 chains in length or thereabouts, a double line, situate partly in the townland of Crossguns South, in the parish of St. George, in the city of Dublin and county of Dublin,

partly in the townlands of Grangegorman Middle, Grangegorman East, Grangegorman West, parish of Grangegorman, city of Dublin and county of Dublin, commencing with junctions to the west end of the existing tramways in Madras Place, passing in a westerly and south-westerly direction along the North Circular Road, and terminating with junctions to the existing lines of tramways on the North Circular Road at Phœnix Park Gate.

Tramway No. 4.—1.5 chains in length or thereabouts, a double line, situate partly in the parishes of St. Anne, St. Peter, and St. Mark, in the city of Dublin, forming junctions from the existing lines of tramways in Merrion Square West, curving round in a northerly and easterly direction, forming junctions with the existing lines of tramways in Merrion Square North.

Tramway No. 5.—A single line, 1 chain in length or thereabouts, situate in the parish of St. Andrew, in the city of Dublin, passing through and beside the present single line of tramway in South Great George's Street, opposite Messrs. Pim Brothers and Company's establishment, forming an interlacing of rails so as to connect the double lines now running into the single line above mentioned with a continuous through line in each case.

STATUTORY RULES AND ORDERS, 1895.—No. 433.

TRAMWAY.

Regulations and Byelaws, dated November 7, 1895, made by the Board of Trade with respect to the Use of Electrical Power under the Bristol Tramways Act, 1894.

The Board of Trade, under and by virtue of the powers conferred upon them in this behalf, do hereby order that the following regulations for securing to the public reasonable protection against danger in the exercise of the powers conferred by Parliament with respect to the use of electrical power on all or any of the tramways on which the use of such power has been authorised by the Bristol Tramways Act, 1894 (hereinafter called "the tramways"), be substituted for all other regulations in this behalf contained in any Tramway Act or Tramway Order confirmed by Act of Parliament.

And the Board of Trade do also hereby make the following byelaws with regard to the use of electrical power on all or any of such tramways:

Regulations.

I.—Every carriage to be used on the tramways shall comply with the following requirements, that is to say:—

(*a*) The wheels of each carriage shall be fitted with brake blocks, which can be applied by a screw or treadle, or by other means.

(*b*) Each carriage shall be numbered inside and outside, and the number shall be shown in conspicuous parts thereof.

(*c*) Each carriage shall be fitted with a suitable fender to push aside obstructions, and with a special bell or whistle to be sounded as a warning when necessary.

(*d*) Arrangements shall be made enabling the driver to command the fullest possible view of the road before him.

(*e*) Each carriage shall be free from the clatter of machinery, such as to constitute any reasonable ground of complaint either to the passengers or to the public, and the machinery shall be concealed from view at all points above 4 in. from the level of the rails.

II.—Every carriage used on the tramways shall be so constructed as to provide for the safety of passengers, and for their safe entrance to, exit from, and accommodation in such

carriages, and for their protection from the machinery used for drawing or propelling such carriages, and shall, when running between sunset and sunrise, or during fog, carry in front a bright coloured light.

III.—The Board of Trade and their officers may, from time to time, and shall on the application of the local authority of any of the districts through which the said tramways pass, inspect the carriages used on the tramways, and the working arrangements generally, and may, whenever they think fit, prohibit the use on the tramways of any of them which, in their opinion, are not safe for use.

IV.—The speed at which the carriages shall be driven or propelled along the tramways shall not exceed the rate of *eight* miles an hour, and the speed at which the carriages shall pass through facing points, whether fixed or movable, shall not exceed the rate of *four* miles an hour.

V.—The speed shall not exceed the rate of *four* miles an hour—

(1) At the junction of Midland Road and West Street.
(2) At the junction of New Road with Clarence Road.
(3) At the junction of Easton Road and Clarence Road.
(4) Between Leadhouse Lane and Packhorse Lane.
(5) Near the junction of Redfield Road and Lyppiatt Road.
(6) In Church Road between Cossham Road and Seneca Street.
(7) At the junction of Bell Hill Road and Marling Road.
(8) On the descending gradient of 1 in 19 in Bell Hill Road.
(9) At the junction of Rodney Road and Bell Hill Road.
(10) At the junction of Two Mile Hill Road and Soundwell Road.
(11) At the junction of High Street and London Street.

VI.—The passengers shall not have access to any portion of the electric circuit.

VII.—All leads and connections used must be of ample size, and must be thoroughly insulated and protected by safety fuses which will operate to break the circuit before the current has risen to an amount which would cause any injurious heating of the conductors, and the length of any safety fuse in the clear shall not be less than 2 in.

VIII.—The electrical pressure or difference of potential between any suspended conductors used in connection with the working of the tramways by electrical power and the earth, or between any two such suspended conductors, shall in no case exceed 500 volts, unless the said suspended conductors are continuously insulated with a durable and efficient material, to be approved by the Board of Trade, to a thickness of not less than $\frac{1}{10}$ in.

IX.—The suspended conductors used in connection with the working of the tramways by electrical power shall be in no part at a less height from the surface of the street than 17 ft., and shall be securely attached to supports at intervals not exceeding 120 ft.

X.—The line wire shall be divided up into sections not exceeding (except with the special approval of the Board of Trade) one quarter of a mile in length, between every two of which shall be inserted an emergency switch and a safety fuse constructed to act with a current exceeding the maximum working current by 50 per cent., which apparatus shall be so enclosed as to be inaccessible to pedestrians.

XI.—Guard wires shall be erected and maintained at all places where telegraph or telephone wires cross above the electric conductors of the tramways.

XII.—All exposed metal in every carriage shall be efficiently connected to earth.

XIII.—Not more than two carriages shall be coupled together, and when two are so running there shall be, in addition to the conductor, a man riding on the front platform of the second carriage, whose sole duty it shall be to attend to the brake, means being provided by

which the driver can signal to this man when he wishes the brake on the rear carriage to be applied.

Penalty.—Any company or person using electrical power on the tramways contrary to any of the above regulations is, for every such offence, subject to a penalty not exceeding £10, and also in the case of a continuing offence, to a further penalty not exceeding £5 for every day after the first during which such offence continues.

BYELAWS.

I.—The special bell or whistle shall be sounded by the driver of the carriage from time to time when it is necessary as a warning.

II.—Whenever it is necessary to avoid impending danger, the carriages shall be brought to a standstill.

III.—The entrance to and exit from the carriages shall be by the hindermost or conductor's platform.

IV.—The carriages shall be brought to a standstill immediately before reaching the following points:—

(1) At Lawrence Hill Railway Station.
(2) At the junction of Bath Road and Church Road.
(3) In Two Mile Hill Road at the junction with Staple Hill Road.

Penalty.—Any person or corporation offending against or committing a breach of any of these byelaws is liable to a penalty not exceeding forty shillings.

The provisions of the Tramways Act, 1870, with respect to the recovery of penalties, is applicable to the penalties for the breach of these regulations or byelaws.

Signed by order of the Board of Trade, this seventh day of November, 1895.

FRANCIS J. S. HOPWOOD,
An Assistant Secretary to the Board of Trade.

STATUTORY RULES AND ORDERS, 1896.—No. 747.

TRAMWAY.

REGULATIONS, DATED AUGUST 17, 1896, MADE BY THE BOARD OF TRADE AS REGARDS ELECTRICAL POWER ON THE DUBLIN SOUTHERN DISTRICT TRAMWAYS.

R. 13,471/96.

The Board of Trade, under and by virtue of the powers conferred upon them in this behalf, do hereby order that the following regulations for securing to the public reasonable protection against danger in the exercise of the powers conferred by Parliament with respect to the use of electrical power on all or any of the tramways on which the use of such power has been authorised by the Dublin Southern District Tramways Act, 1893 (herein-after called "the tramways"), be substituted for all other regulations in this behalf contained in any Tramway Act or Tramway Order confirmed by Act of Parliament:

And the Board of Trade do also hereby make the following byelaws with regard to the use of electrical power on all or any of such tramways.

REGULATIONS.

I.—Every motor carriage used on the tramways shall comply with the following requirements, that is to say:

(*a*) The wheels shall be fitted with break blocks, which can be applied by a screw or treadle, or by other means, and there shall be in addition an adequate electric brake.

(*b*) It shall be fitted within six months from the date hereof with a governor which cannot be tampered with by the driver, and which shall operate so as to cut off all electric current from the motors whenever the speed exceeds *ten* miles an hour.

(*c*) It shall be numbered inside and outside, and the number shall be shown in conspicuous parts thereof.

(*d*) It shall be fitted with a suitable fender, which will act efficiently as a life protector, and with a special bell or whistle to be sounded as a warning when necessary.

(*e*) It shall be so constructed as to enable the driver to command the fullest possible view of the road before him.

(*f*) It shall be free from the clatter of machinery, such as to constitute any reasonable ground of complaint, either to the passengers or to the public, and any machinery under the carriage shall be concealed from view at all points above four inches from the level of the rails.

(*g*) When running between sunset and sunrise, or during fog, it shall carry in front a bright coloured light.

II.—Every trailing carriage used on the tramways shall comply with the following requirements, that is to say:—

(*a*) The wheels shall be fitted with break blocks, which can be applied by a screw or treadle or by other means.

(*b*) It shall be numbered inside and outside, and the number shall be shown in conspicuous parts thereof.

III.—Not more than two carriages shall be coupled together, and when two are so running there shall be, in addition to the conductor, a man on the front platform of the second carriage, whose sole duty it shall be to attend to the brake, means being provided by which the driver can signal to this man when he wishes the brake on the rear carriage to be applied. The carriages shall be connected by double couplings, one of which shall be a screw coupling.

IV.—Every carriage used on the tramways shall be so constructed as to provide for the safety of passengers, and for their safe entrance to, exit from, and accommodation in such carriages, and for their protection from the apparatus used for drawing or propelling the carriages.

V.—The Board of Trade and their officers may, from time time, and shall, on the application of the local authority of any of the districts through which the said tramways pass, inspect the carriages used on the tramways, and the working arrangements generally, and may, whenever they think fit, prohibit the use on the tramways of any of them which, in their opinion, are not safe for use.

VI.—The speed at which the carriages shall be driven or propelled along the tramways shall not exceed the rate of *eight* miles an hour, and the speed at which the carriages shall pass facing points, whether fixed or moveable, shall not exceed the rate of *four* miles an hour.

VII.—The speed shall not exceed the rate of *four* miles an hour in Upper George Street between Mulgrave Street and Mellifont Avenue, or on the road between Merrion Avenue and the boundary between the parishes of Booterstown and Monkstown, and not more than one carriage or two carriages coupled together shall be allowed on the first-mentioned portion of the tramway at one and the same time.

VIII.—The passengers shall not have access to any portion of the electric circuit.

IX.—All electric mains, leads and connexions used must be of ample size and must be thoroughly insulated and protected by safety fuses or other cut-outs which will operate to break the circuit before the current has risen to an amount which would cause any injurious heating

of the conductors, and the length of any safety fuse in the clear shall not be less than two inches.

X.—The electrical pressure or difference of potential between any suspended conductors used in connexion with the working of the tramways by electrical power and the earth, or between any two such suspended conductors, shall in no case exceed 500 volts continuous pressure.

XI.—The suspended conductors used in connexion with the working of the tramways by electrical power shall be in no part at a less height from the surface of the street than 17 feet, and shall be securely attached to supports at intervals not exceeding 120 feet.

XII.—The line wire shall be divided up into sections not exceeding (except with the special approval of the Board of Trade) one quarter of a mile in length, between every two of which shall be inserted an emergency switch and a safety fuse or cut-out constructed to act with a current exceeding the maximum working current by 50 per cent., which apparatus shall be so enclosed as to be inaccessible to pedestrians.

XIII.—The electrical pressure between the conductors in any electric line or between any such conductor and the earth shall not in any case exceed 3,000 volts.

XIV.—All electric lines laid for the purpose of supply to transforming stations on the "three phase system" shall have their conductors arranged concentrically, the outer conductor being efficiently connected with earth at the generating station, but insulated at all other points; and the thickness of insulation between the several conductors of any such electric line shall not be less in parts of an inch than the number obtained by dividing the number expressing the maximum electrical pressure in volts by 20,000. No such electric line shall be brought into use unless the insulation of every part thereof has withstood the continuous application during one hour of twice the maximum pressure to which it is intended to be subjected in use.

XV.—The sectional area of the conductor in any electric line laid or erected in any street after the date of these regulations shall not be less than the area of a circle of one-tenth of an inch diameter, and where the conductor is formed of a strand of wires, each separate wire shall be at least as large as No. 20 standard wire gauge: Provided that this regulation shall not apply to any electric line connected to the rails for the purpose of measuring the fall of potential in the return, and not otherwise connected with the electric circuit.

XVI.—No part of any electric line shall be used for the transmission of more than 300,000 watts, except with the consent in writing of the Board of Trade, and efficient means shall be provided to prevent this limit being at any time exceeded.

XVII.—All electrical conductors fixed upon the carriages in connection with the "trolley wheel" shall be formed of flexible cables protected by india-rubber insulation of the highest quality, and additionally protected wherever they are adjacent to any metal, so as to avoid risk of the metal becoming charged.

The insulation resistance between these conductors and the "trolley standard" and the metal fittings on the carriages respectively shall be tested daily with the full working electrical pressure, and shall not be permitted to fall below the following amounts respectively, viz.:—

Between conductors and trolley standard	... ...	10 megohms.
" " metal fittings	... ...	1 megohm.

XVIII.—All metal fittings upon the roofs of the carriages within six feet of the trolley standard shall be carefully covered with insulating material to a thickness of at least $\frac{1}{16}$ inch, and this covering shall be constantly maintained in efficient condition.

XIX.—An emergency cut-off switch shall be provided and fixed so as to be conveniently reached by the driver in case of any failure of action of the controller switch.

XX.—Efficient guard wires shall be erected and maintained at all places where telegraph or telephone wires cross above the electric conductors of the tramways.

XXI.—Where any portion of any electric line or any support for an electric line is exposed in such a position as to be liable to injury from lightning, it shall be efficiently protected against such injury.

XXII.—Where any accident by explosion or fire, or any other accident of such kind as to have caused or to be likely to have caused loss of life or personal injury has occurred in connexion with the electric working of the tramways, immediate notice thereof shall be given to the Board of Trade.

Penalty.—Any company or person using electrical power on the tramways contrary to any of the above regulations is, for every such offence, subject to a penalty not exceeding £10, and also in the case of a continuing offence, to a further penalty not exceeding £5 for every day after the first during which such offence continues.

BYELAWS.

I.—The special bell or whistle shall be sounded by the driver of the carriage from time to time when it is necessary as a warning.

II.—Whenever it is necessary to avoid impending danger, the carriages shall be brought to a standstill.

III.—The entrance to and exit from the carriages shall be by the hindermost or conductor's platform.

IV.—The carriages shall be brought to a standstill immediately before passing round the spot known as Hynes Corner.

V.—A printed copy of these regulations and byelaws shall be kept in a conspicuous position inside of each carriage in use on the tramways.

Penalty.—Any person or corporation offending against or committing a breach of any of these byelaws is liable to a penalty not exceeding forty shillings.

The provisions of the Tramways Act, 1870, with respect to the recovery of penalties are applicable to the penalties for the breach of these regulations or byelaws.

Signed by order of the Board of Trade, this 17th day of August, 1896.

FRANCIS J. S. HOPWOOD,
An Assistant Secretary to the Board of Trade.

PARLIAMENTARY AND OFFICIAL REGULATIONS.

I. THE TRAMWAYS ACT, 1870.

This statute, 33 and 34 Vict., c. 78, the full title of which is "An Act to Facilitate the Construction and to Regulate the Working of Tramways," is the principal enactment dealing with tramways in Great Britain. The Act does not extend to Ireland (s. 2). Previous to the passing of the Act the decisions of the Examiner and of the Standing Committee of the House of Lords on the Liverpool Tramway Bill of 1866 had rendered it necessary for promoters of tramways to deposit plans and sections of their proposed undertakings.

PROVISIONAL ORDERS.

Part I. of the Act deals with Provisional Orders authorising the construction of tramways, and provides (s. 4) that the local authority (see post, p. 673) of any district may obtain such Orders for tramways in their district; and the like power is given to any other person or

persons, corporation or company, with the consent of the Board of Trade and the local authority, but not otherwise. Any such local authority, person, persons, corporation, or company obtaining such Provisional Order are to be deemed promoters of the tramway (s. 4).*

Upon application for a Provisional Order being made to the Board of Trade, the Board are to consider the application, and may, if they think fit, direct inquiries as to the propriety of proceeding upon such application; and they are to consider any objection thereto that may be lodged with them, and to determine whether or not the promoters may proceed with the application (s. 7).

At pages 673-693, post, will be found the full text of the rules issued by the Board of Trade with respect to Provisional Orders.

Where it appears to the Board of Trade expedient, they may make a Provisional Order, which order shall empower the promoters to make the tramway upon the gauge and in the manner therein described, and shall contain such provisions as (subject to the requirements of the Act) the Board of Trade, according to the nature of the application and the facts and circumstances of each case, shall think fit; but such Order is not to contain any provision for acquiring lands, except to an extent therein limited, and only then by agreement, or to construct a tramway elsewhere than along or across a road, or upon land taken by agreement (s. 8).

Tramways shall be constructed as near as may be in the middle of the road, and shall not be so laid that, for a distance of 30 feet or upwards, a less surface than 9 feet 6 inches shall intervene between the outside of the footpaths on either side of the road and the nearest rail of the tramway, if one-third of the owners or one-third of the occupiers of the houses, shops, or warehouses abutting upon the part of the road where such less space shall intervene, as aforesaid, express their dissent from any tramway being so laid (s. 9).

The nature of the traffic on the tramway, and the tolls to be taken, are to be specified in the Provisional Order (s. 10).

The Provisional Order is not to be granted until the promoters deposit in a bank, as there prescribed, a sum of not less than 4 per cent. upon the estimated expenses, or security of equal value is deposited (s. 12).

The Provisional Order is not to have any operation until confirmed, with or without amendment, by an Act of Parliament, and it is to be open to parties to petition against the Act, and to appear and oppose the Bill in Committee (s. 14).

The Board of Trade, on the application of the promoters, may revoke, amend, extend, or vary such Provisional Order by a further Provisional Order, but the application for every such Provisional Order will be subject to the same conditions as the former Provisional Order, and will require confirmation by an Act of Parliament (s. 16).

If the promoters do not complete the tramway and open it for public traffic within two years of the date of the Order, or within any shorter period prescribed in the Order; or if, within one year from either of those times, the works are not substantially commenced, or, if commenced, are suspended without a reason sufficient in the opinion of the Board of Trade, the powers given by the Order shall cease, except as to so much of the same as is then completed, unless the time be prolonged by the Board; and as to so much of the same as is then completed, the Board may allow the powers to continue and to be exercised if they think fit; but, failing such permission, then so much of the tramway as is then completed shall be deemed to be discontinued and dealt with accordingly (s. 18).

* Tramways Orders Confirmation Acts. Provisional Orders made by the Board of Trade under the authority of the Tramways Act, 1870, to acquire final validity and force, must be confirmed by special Acts of Parliament. These are distinguished as "Tramways Orders Confirmation Acts," by which the orders set out in the schedules to the Acts respectively are confirmed.

When a tramway has been made by a Local Authority, or possession has been acquired by a Local Authority, they may, with the consent of the Board of Trade, lease to any person the right of user thereof, and of demanding and taking authorized tolls and charges; or the Local Authority may leave such tramways open to be used by the public, and may, in respect of such cases, take the tolls and charges authorized; but no Local Authority can place or run carriages upon such tramways, and demand and take tolls and charges in respect of the use of such carriages. Every such lease shall be made for a term not exceeding twenty-one years, and at its expiration such lease may, with the consent of the Board, be renewed for a further term not exceeding in any case twenty-one years; the lease to be void if the lesses discontinue the working of the tramway (s. 19).

Special provision is made by the Act for payment out of the local rate of all expenses incurred by a Local Authority in obtaining and carrying into effect a Provisional Order authorising the construction of tramways (ss. 20, 21).

Construction of Tramways.

Part II. of the Act relates to the construction of tramways, and (together with Part III.) is to be incorporated with every Provisional Order or special Act authorising a tramway, except so far as they may be expressly varied thereby (ss. 22, 23, 24).

If no gauge is prescribed by the special Act, the gauge is to be such as to admit of the use on the tramways of carriages constructed for use upon railways of a gauge of 4 feet $8\frac{1}{2}$ inches. They are to be laid on a level with the surface of the road (s. 25).

Powers are given to promoters to break up streets, and provision is made for the completion of the works and the re-instatement of the road, for the repair of the part of the road where the tramway is laid, and for contracts between the road authority and the promoters for paving roads on which tramways are laid; also for the case of interference with the mains of gas and water companies, and for the protection of sewers, drains, and the like (ss. 26, 31).

The Act further preserves the rights of authorities and companies, etc., to open roads (s. 32), and provides for the settlement of all differences that may arise between the promoters and the road authority or other body or person by a referee to be appointed by the Board of Trade (s. 33).

General Provisions.

Part III. of the Act contains general provisions relating to the working of tramways.

Carriages.—The promoters are to have the exclusive use of the tramways for carriages with flange wheels, or other wheels suitable only to run on the prescribed rail, to be moved by the power prescribed by the special Act, and, where no such power is prescribed, by animal power only. No carriage shall extend beyond the outer edge of the wheels of such carriage more than 11 inches on each side (s. 34).

Licenses.—If the local authority or twenty inhabitant ratepayers satisfy the Board of Trade that the public are deprived of the full benefit of the tramway, licenses to use it may be granted to third parties by the Board of Trade on certain conditions, provision being made by the Act for enforcing payment of tolls, etc. (ss. 35, 41).

Discontinuance of Tramways.—If the working of a tramway, or of any part thereof, is discontinued for the space of three months (such discontinuance not being occasioned by circumstances beyond the control of the promoters), the powers of the promoters in respect of such disused tramway or portion thereof, may be determined by an order of the Board of Trade. At any time after two months from the date of such order, the road authority may remove the disused portion of tramways at the cost of the promoters (s. 41).

Insolvency of Promoters.—If at any time after opening of a tramway for traffic the promoters appear to be insolvent or unable to maintain the tramway, the Board of Trade, on the application of the local authority or road authority, and after inquiry by a referee, may make an order declaring that the powers of the promoters shall cease at the expiration of six months from the date of the order, unless the same are purchased by the local authority, who may, in that event, remove the tramway at the cost of the promoters (s. 42).

Purchase and Sale of Tramways.—Where the promoters of a tramway are not the local authority, the local authority may, within six months after the expiration of a period of twenty-one years from the time when such promoters were empowered to construct such tramway, and within six months after the expiration of every subsequent period of seven years, or within three months after any order made by the Board of Trade under ss. 41, 42, with the approval of the Board of Trade, require the promoters to sell their undertaking, upon terms of paying the then value (exclusive of any allowance for past or future profits of the undertaking, or any compensation for compulsory sale, or other consideration whatsoever) of the tramway, and all lands, buildings, works, materials and plant of the promoters suitable to and used by them for the purpose thereof, such value to be in case of difference determined by a referee nominated by the Board of Trade.

The local authority in any district may pay the purchase money and all expenses incurred by them in so purchasing an undertaking out of the like rate, and shall have the like powers of borrowing on the security of the rate, as if such expenses were incurred in obtaining and carrying into effect a Provisional Order under the Act.

Two or more local authorities may jointly purchase any undertaking within their several districts (s. 43).

Where a tramway has been opened for traffic for six months the promoters may, with the consent of the Board of Trade, sell their undertaking to any person, persons, corporation or company, or to the local authority of the district; and where such sale is made to the local authority, such local authority may pay the purchase money in like manner as if such purchase were made under the authority of the 43rd section (s. 44).

Tolls.—The promoters or lessees of a tramway authorised by special act may demand and take tolls and charges as specified in the special Act. such tolls and charges to be exhibited in a conspicuous place inside and outside each tramway carriage (s. 45).

Byelaws.—The local authority are empowered to make byelaws as to the rate of speed, the clear distances between any two carriages travelling on the same line of rails, the stopping of carriages using the tramway, and the traffic on the road in which the tramway is laid; and the promoters or lessees of a tramway may also make byelaws for the prevention of any nuisance in or about their carriages or premises, and the regulation of travelling upon their carriages. The byelaws are to be subject to allowance by the Board of Trade, and may prescribe penalties (ss. 46, 47).

(For forms of byelaws issued by the Board of Trade, see post p. 694).

Power is given to the local authority to license the drivers and conductors of tramways (s. 48).

Offences.—Penalties are imposed for obstruction of promoters in laying out a tramway; for wilful injury or obstruction to tramways or works; for frauds practised or attempted by passengers; for bringing dangerous goods on a tramway, &c. (ss. 49, 53).

Any person, not duly authorised, using a tramway with carriages having flange wheels, or other wheels suitable only to run on such tramway, becomes liable to a penalty not exceeding £20 (s. 54).

Accidents and Injuries.—The promoters or lessees are to be answerable for all accidents, damages, and injuries happening through their act or through the act of default of any person

in their employment, by reason or in consequence of any of their works or carriages (s. 55).

Recovery of Tolls and Penalties.—All tolls, penalties, and charges under the Act, or under a byelaw, may be recovered and enforced in England before two justices of the peace under the Summary Conviction Act, and in Scotland before the sheriff or two justices as penalties under the Railway Clauses Consolidation (Scotland) Act, 1845 (s. 56).

Right of User of Road only.—The promoters of a tramway shall not be deemed to acquire any right other than that of user of any road along or across which they lay the tramway, and nothing contained in the Act is to exempt the promoters, or other person using a tramway, from the payment of tolls to the trustees of a turnpike road. With the approval of the Board of Trade, the trustees of a turnpike road and the promoters of a tramway may enter into agreements for the payment of a composition in respect of the user of such road (ss. 57, 58).

Mines and Minerals under Tramways.—Nothing in the Act is to limit or interfere with the rights of any owner or occupier of mines or minerals lying under or adjacent to a road along or across which a tramway is laid; nor shall any such owner or occupier be liable to make compensation for damage occasioned to such tramway by the working of the mines in ordinary course (s. 59).

Public Rights.—Nothing in the Act is to restrict the powers by law of existing authorities to widen, alter, divert, or improve any road, railway, tramway, or inland navigation; or to limit the powers of the police of local authorities to regulate the traffic of the road; or to abridge the right of the public to pass along or across any part of a road along or across which a tramway is laid with carriages not having flange wheels (ss. 60, 61, 62).

Public Inquiries.—Inquiries which by the Act of the Board of Trade are empowered to make are to be made according to the provisions set forth in the Act (s. 63).

Board of Trade Rules.—Power is given to the Board of Trade from time to time to make and amend rules for carrying the Act into effect; and any rules so made are to be laid before Parliament (s. 64).

II. BOARD OF TRADE RULES WITH RESPECT TO PROVISIONAL ORDERS AND OTHER MATTERS UNDER THE TRAMWAYS ACT, 1870.*

By whom Provisional Orders may be Obtained, and the Necessary Consents Thereto.

By the Tramways Act, 1870, it is provided as follows:—

"Part I. Provisional Orders authorising the construction of tramways.

Section 4. "Provisional Orders authorising the construction of tramways in any district may be obtained by—

"(1) The local authority of such district; or by

"(2) Any person, persons, corporation or company, with the consent of the local authority of such district; or of the road authority of such district, where such district is or forms part of a highway district formed under the provisions of 'The Highway Acts.'

"Application for a Provisional Order shall not be made by any local authority until such application shall be approved in the manner prescribed in Part III. of the Schedule A. to this Act annexed. (This schedule follows on page 624).

* (1) All memorials, objections, and other documents addressed to the Board of Trade under the Act should be on paper of foolscap size. (2) Promoters who desire to be incorporated must register themselves under the Companies' Act, 1862.

"Where in any district there is a road authority distinct from the local authority, the consent of such road authority shall also be necessary in any case where power is sought to break up any road subject to the jurisdiction of such road authority, before any Provisional Order can be obtained."

Definition of Terms.—Section 3 provides that for the purposes of the Act, the terms "local authority" and "local rate" shall mean respectively the bodies of persons and rate named in the table in Part I. of the Schedule (A.) to this Act annexed.

The term "road" shall mean any carriageway being a public highway, and the carriageway of any bridge forming part of or leading to the same.

The term "road authority" shall mean, in the districts specified in the table in Part II. of the Schedule (A) to this Act annexed, the bodies of persons named in the same table, and elsewhere any local authority, board, town council, body corporate, commissioners, trustees, vestry, or other body or persons in whom a road as defined by this Act is vested, or who have the power to maintain or repair such road.

The term "district" in relation to a local authority or road authority shall mean the area within the jurisdiction of such local authority or road authority.

"SCHEDULE A. PART I.

"*Local Authority.*

Districts of Local Authorities.	Description of Local Authority of District opposite its Name.	The Local Rate.
	ENGLAND AND WALES.	
The City of London and the liberties thereof.	The mayor, aldermen, and commons of the City of London.	The consolidated sewers rate.
The metropolis (*a*).	The Metropolitan Board of Works (*c*).	The metropolitan consolidated rate.
Boroughs (*b*).	The mayor, alderman, and burgesses acting by the council.	The borough fund, or other property applicable to the purposes of a borough rate.
Any place not included in the above descriptions, and under the jurisdiction of commissioners, trustees, or other persons intrusted by any local Act with powers of improving, cleansing, or paving any town.	The commissioners, trustees, or other persons intrusted by the local Act with powers of improving, cleansing, or paving the town.	Any rate leviable by such commissioners, trustees, or other persons, or other funds applicable by them to the purposes of improving, cleaning, or paving the town.
Any place not included in the above descriptions, and within the jurisdiction of a local board constituted in pursuance of the Public Health Act, 1848, and the Local Government Act, 1858, or one of such Acts.	The local board.	General district rate.
Any place or parish not within the above descriptions, and in which a rate is levied for the maintenance of the poor.	The vestry, select vestry, or other body of persons acting by virtue of any Act of Parliament, prescription, custom, or otherwise, as or instead of a vestry or select vestry.	The poor rate.

"(*a*) 'The metropolis' shall include all parishes and places in which the Metropolitan Board of Works have power to levy a main drainage rate, except the City of London and the liberties thereof.

"(*b*) 'Borough' shall mean any place for the time being subject to an Act passed in the session holden in the fifth and sixth years of the reign of King William the Fourth, chapter seventy-six, intituled 'An Act to provide for the regulation of municipal corporations in England and Wales.'

"(*c*) Now London County Council.

Districts of Local Authorities.	Description of Local Authority of District opposite its Name.	The Local Rate.
	SCOTLAND.	
Places within the jurisdiction of any town council, and not subject to the separate jurisdiction of police commissioners or trustees.	The town council.	The prison assessment or police assessment, as the local authority shall resolve.
In places within the jurisdiction of police commissioners, or trustees exercising the functions of police commissioners, under any general or local Act.	The police commissioners or trustees.	
In any parish or part thereof over which the jurisdiction of a town council or of police commissioners or trustees exercising the functions of police commissioners does not extend.	The road trustees having the management of any road on which a tramway is proposed to be constructed.	The tolls, duties, and assessments leviable by the road trustees.

"SCHEDULE A. PART II.

"*Road Authority.*

Districts of Road Authorities.	Description of Road Authority of Districts set opposite its Name.
Parishes within the Metropolis (1) mentioned in Schedule A to the Metropolis Management Act, 1855.	The vestries appointed for the purposes of the Metropolis Management Act, 1855.
Districts within the Metropolis (1) formed by the union of the parishes mentioned in Schedule B to the Metropolis Management Act, 1855.	The board of works for the district appointed for the purpose of the Metropolis Management Act, 1855.

"SCHEDULE A. PART III.

"*Evidence of Approval and Consent.*—The approval of any intended application for a Provisional Order by a local authority shall be in manner following; that is to say:—

"A resolution approving of the intention to make such application shall be passed at a special meeting of the members constituting such local authority.

"Such special meeting shall not be held unless a month's previous notice of the same, and of the purpose thereof, has been given in the manner in which notices of meetings of such local authority are usually given.

"Such resolution shall not be passed unless two-thirds of the members constituting such local authority are present and vote at such special meeting, and a majority of those present and voting concur in the resolution; provided that if in Scotland the local authority be the road trustees, it shall not be necessary that two-thirds of such trustees shall be present at the meeting; but the resolution shall not be valid unless two-thirds of the members present vote in favour of such resolution, and unless the said resolution is confirmed in like manner at another meeting called as aforesaid, and held not less than three weeks and not more than six weeks thereafter. Where any such resolution relating to the metropolis as the same is defined in Part I. of the Schedule, or to any district in Scotland of which road trustees are the local authority, has been passed in manner aforesaid, the intended application to which such resolution relates shall be deemed to be approved."

RULES OF THE BOARD OF TRADE.

Rule I. *Approval of Application made by Local Authorities.*—Where the application is made by any local authority, the evidence of approval required as above by Schedule A (Part III.) of the Act must be given at the time fixed for proving compliance with the Act and these Rules, by (*a*) a certified copy of the resolution approving of the intention to make the application, (*b*) a certified copy of the notice convening the special meeting to consider the application, and (*c*) a certified statement of the number of members constituting the local authority, and of the number present and voting at such special meeting.

Rule II. *Consent to Applications not made by Local Authorities.*—Where an application is made by promoters, not being the local authority of the district in which the tramway is proposed to be laid, evidence of the consent required by Part I., section 4 of the Act, must be given at the time fixed for proving compliance with the Act and these Rules, by (*a*) a certified copy of the resolution passed at a meeting of the local or road authority, as the case may be, at which the application was approved; (*b*) a copy of the notice convening the meeting, which notice must contain a statement that the subject of the proposed tramway will be brought before the meeting.

Similar evidence of the consent of the local and road authorities must be produced in cases in which the promoters seek to use steam or other mechanical power on any tramway or tramways already authorised.

ADVERTISEMENT AND NOTICES IN OCTOBER OR NOVEMBER AND DECEMBER.

Section 6.—" The promoters intending to make an application for a Provisional Order shall proceed as follows :—

"(1) In the months of October and November next before the application, or in one of those months, they shall publish notice of their intention to make such application by advertisement ; and they shall, on or before the fifteenth day of the following month of December, serve notice of such intention in accordance with the Standing Orders (if any) of both Houses of Parliament for the time being in force with respect to Bills for the construction of tramways. (See Schedule B, Part I.)

"(2) On or before the thirtieth day of the same month of November they shall deposit the documents described in Part II. of the same* Schedule, according to the regulations therein contained.

"(3) On or before the twenty-third day of December in the same year they shall deposit the documents described in Part III. of the same† Schedule, according to the regulations therein contained."

SCHEDULE B. PART I.

"(1) Every advertisement is to contain the following particulars :—

" 1. The objects of the intended application.

" 2. A general description of the nature of the proposed works (if any).

" 3. The names of the townlands, parishes, townships, and extra-parochial places in which the proposed works (if any) will be made.

" 4. The times and places at which the deposit under Part II. of this Schedule will be made.

" 5. An office, either in London or at the place to which the intended application relates, at which printed copies of the Draft Provisional Order, when deposited, and of the Provisional Order, when made, will be obtainable as hereinafter provided.

* Schedule B. † Schedule B.

"(2) The whole notice is to be included in one advertisement, which is to be headed with a short title descriptive of the undertaking.

"(3) The advertisement is to be inserted once at least in each of two successive weeks in some one and the same newspaper published in the district affected by the proposed undertaking, where the proposed works, if any, will be made; or if there be no such newspaper, then in some one and the same newspaper published in the county in which every such district, or some part thereof, is situate; or if there be none, then in some one and the same newspaper published in some adjoining or neighbouring county.

"(4) The advertisement is also, in every case, to be inserted once at least in the London or Edinburgh Gazette, accordingly as the district is situate in England or Scotland."

Rule III. *Description of Tramways in Advertisement.*—The tramways mentioned in the advertisement of the intended application should be described in the manner prescribed in Rule XVI., but the length need not be inserted.

Rule IV. *Advertisement as to Narrow Places.*—The advertisement must specify at what point or points, and on which side of the street or road, it is proposed to lay such tramway, so that for a distance of 30 ft. or upwards a less space than 9 ft. 6 in., or if it is intended to run thereon carriages or trucks adapted for use upon railways, a less space than 10 ft. 6 in., shall intervene between the outside of the footpath on the side of the street or road and the nearest rail of the tramway. The notice shall also specify the gauge to be adopted, and what power it is intended to employ for moving carriages or trucks upon the tramway.

Rule V. *Street Notice.*—In the months of October and November, or one of them, immediately preceding the application for any Provisional Order, a notice thereof shall be posted for fourteen consecutive days in every street or road along which it is proposed to lay the tramway, in such manner as the authority having the control of such street or road shall direct; and if after application to such authority no such direction shall be given, then in some conspicuous position in such street or road; and such notice shall also state the place or places at which the plans of such tramway will be deposited.

Rule VI. *Notice to Owners and Lessees of Railways, Tramways, and Canals.*—On or before the fifteenth day of December immediately preceding the application for any Provisional Order for laying down a tramway crossing any railway or tramway on the level, or crossing any railway, tramway, or canal by means of a bridge, or otherwise affecting or interfering with such railway, tramway, or canal, notice in writing of such application shall be served upon the owner or reputed owner and upon the lessee or reputed lessee of such railway, tramway, or canal, and such notice shall state the place or places at which the plans of the tramway to be authorised by such Provisional Order have been or will be deposited.

Similar notice must also be given to County Councils and to proprietors of navigable rivers in respect of their bridges or other works which are proposed to be crossed or otherwise interfered with.

Every notice under this rule must be accompanied by a copy of Rule XVII., omitting the first paragraph, and must state where copies of the draft Provisional Order, when deposited at the Board of Trade, can be obtained.

Rule VII. *Notice to Local and Road Authorities.*—Where the promoters make application for an extension of time for the construction of, or for authority to abandon any tramway, they must, on or before the 15th day of December, serve notice of such application upon all the local and road authorities affected.

Rule VIII. *Intimation to Intending Objectors.*—The preceding advertisement in notices, other than the street notice, must state that every company, corporation or person desirous of making any representation to the Board of Trade, or of bringing before them any objection respecting the application, may do so by letter, addressed to the Assistant Secretary of the

Railway Department of the Board of Trade, *on or before the 15th January next ensuing*; that copies of their objections must at the same time be sent to the promoters; and that in forwarding to the Board of Trade such objections, the objectors or their agents should state that a copy of the same has been sent to the promoters or their agents.

Rule IX. *Notice to Frontagers.*—On or before the 15th day of December immediately preceding the application for a Provisional Order, notice in writing must be given to the owners or reputed owners, lessees or reputed lessees, and occupiers of all houses, shops, or warehouses, abutting upon any part of the street or road where, for a distance of 30 ft. or upwards, it is proposed that a less space than 9 ft. 6 in. shall intervene between the outside of the footpath on either side of the road and the nearest rail of the tramway.

This notice shall be given in respect of such premises on both sides of the road, and must contain a notification that if such owner, lessee, or occupier dissents from the tramway being so laid, he may express his dissent by a statement in writing addressed to the Assistant Secretary of the Railway Department of the Board of Trade, on or before *the 1st January next ensuing*, and that he must at the same time send a copy of his dissent to the promoters.

DEPOSITS ON OR BEFORE 30TH NOVEMBER.

Schedule B. Part II.

"(1) The promoters are to deposit—

"1 A copy of the advertisement published by them.

"2 A proper plan and section of the proposed works, if any; such plan and section to be prepared according to such regulations as may from time to time be made by the Board of Trade in that behalf.

"(2) The documents aforesaid are to be deposited for public inspection—

"In England, in the office of the clerk of the peace for every county, riding, or division, and of the parish clerk of every parish, and the office of the local authority of every district in or through which any such undertaking is proposed to be made; in Scotland, in the office of the principal sheriff clerk for every county, district, or division which will be affected by the proposed undertaking, or in which any proposed new work will be made.

"(3) The documents aforesaid are also to be deposited at the office of the Board of Trade."

Rule X. *Map and Diagram.*—A published map of the district on a scale of not less than six inches to a mile (or, if no map on such a scale be published, then the best map obtainable), with the line of the proposed tramway marked thereon, and a diagram on a scale of not less than two inches to a mile, prepared in accordance with the specimen appended to these rules, must also be deposited on or before the 30th of November.

Rule XI. *Requirements as to Plans.*—The plans to be deposited must also comply with the following requirements:—

The plans shall indicate whether it is proposed to lay the tramway along the centre of any street or road, and if not along the centre, then on which side of, and at what distance from, an imaginary line drawn along the centre of such street or road; and whether or not, and if so, at what point or points it is proposed to lay such tramway, so that for a distance of thirty feet or upwards a less space than nine feet six inches, or if it is intended to run thereon carriages or trucks adapted for use upon railways, a less space than ten feet six inches, shall intervene between the outside of the footpath on either side of the street or road and the nearest rail of the tramway.

All lengths shall be stated on the plan and section in miles, furlongs, chains, and decimals of a chain.

The distance in miles and furlongs from one of the termini of each tramway shall be marked on the plan and section.

Each double portion of tramway, whether a passing-place or otherwise, shall be indicated by a double line.

The total length of the street or road upon which each tramway is to be laid shall be stated (*i.e.*, the length of route of each tramway).

The length of each double and single portion of such tramway, and the total length of such double and single portions respectively, shall also be stated.

In the case of double lines (including passing-places), the distance between the centre lines of each line of tramway shall be marked on the plans. This distance must in all cases be sufficient to leave at least fifteen inches between the sides of the widest carriage and engines to be used on the tramways when passing one another.

The gradients of the street or road on which each tramway is to be laid shall be marked on the section.

Every crossing of a railway, tramway, river, or canal, shall be shown, specifying in the case of railways and tramways whether they are crossed over, under, or on the level.

All tidal waters shall be coloured blue.

All places where for a distance of thirty feet and upwards there will be a less space than nine feet six inches between the outside of the footpath on either side of the street or road and the nearest rail of the tramway shall be indicated by a thick dotted line on the plans and on the side or sides of the line of tramway where such narrow places occur, as well as noted on the plans, and the width of the street or road at these places shall also be marked on the plan.

Note.—The section of each tramway should, where practicable, be shown on the same page as the plan.

Rule XII. *Plans in certain cases to be in Duplicate.*—The plans to be deposited with the clerk of the peace or sheriff clerk (as the case may be), must be in duplicate. (See Standing Orders of the House of Lords and of the House of Commons.)

Rule XIII. *Portions only of Plans required in certain cases.*—In cases where the proposed works are intended to be made in or through one or more parishes or districts, the deposit with the parish clerks or local authorities need consist only of a copy of so much of the plans and sections as relates to their respective parishes or districts.

Rule XIV. *Plans, etc., to be deposited in Parliament.*—The following Standing Orders must also be complied with.*

STANDING ORDER OF THE HOUSE OF LORDS.

"Whenever plans, sections, books of reference, or maps, are deposited in the case of an application to any public department or county council for a Provisional Order or certificate, duplicates shall at the same time be deposited in the office of the Clerk of the Parliament; provided that with regard to such deposits as are so made at any public department or with any county council after the prorogation of Parliament and before the thirtieth day of November in any year, such duplicates shall be so deposited on or before the thirtieth day of November."

STANDING ORDER OF THE HOUSE OF COMMONS.

"Whenever plans, sections, books of reference, or maps, are deposited in the case of any application to any public department or county council for a Provisional Order or Provisional Certificate, duplicates of the said documents shall at the same time be deposited in the Private

* These Standing Orders refer to amended as well as original plans.

Bill Office; provided that with regard to such deposits as are so made at any public department or with any county council after the prorogation of Parliament and before the thirtieth day of November in any year, such duplicates shall be so deposited on the thirtieth day of November."

DEPOSITS ON OR BEFORE 23RD DECEMBER.

Schedule B. Part III.

"(1) The promoters are to deposit at the office of the Board of Trade—

"1. A memorial signed by the promoters, headed with a short title descriptive of the undertaking (corresponding with that at the head of the advertisement), addressed to the Board of Trade, and praying for a Provisional Order.

"2 A printed draft of the Provisional Order as proposed by the promoters, with any schedule referred to therein.

"3 An estimate of the expense of the proposed works, if any, signed by the person making the same.

"(2) They are also to deposit a sufficient number of such printed copies at the office named in that behalf in the advertisement; such copies to be there furnished to all persons applying for them, at the price of not more than one shilling each.

"(3) The memorial of the promoters (to be written on foolscap paper, bookwise, with quarter margin) is to be in the following form, with such variations as circumstances require :—

(Short title of undertaking.)

"To the Board of Trade.

"The Memorial of the promoters of (short title of undertaking).

"Showeth as follows :—

"1. Your memorialists have published, in accordance with the requirements of the Tramways Act, 1870, the following advertisement :—

(Here advertisement to be set out verbatim*).

"Your memorialists have also deposited, in accordance with the requirements of the said Act, copies of the said advertisement and (here state deposit of the several matters required by Act).

"Your memorialists therefore pray that a Provisional Order may be made in the terms of the draft proposed by your memorialists, or in such other terms as may seem meet.

"A. B. } Promoters."
"C. D. }

Rule XV. The following documents, etc., must also be deposited at the Board of Trade on or before the 23rd December, viz. :—

(1) *List of Railways, Tramways, and Canals, and Copy of the Notice.*—A complete list of every railway, tramway, and canal proposed to be crossed or otherwise affected or interfered with, together with the names and addresses of the owners or reputed owners, and of the lessees or reputed lessees thereof, and a certified copy of the notice served upon them.

(2) *Lists of Local and Road Authorities and Copy of Notice.*—A complete list of the local and of the road authorities through whose districts the proposed tramway is to pass (including in such list the clerk to the County Council in cases where it is proposed to cross county bridges), and if any such district is or forms part of a highway district, under the provisions of "The Highway Acts," a statement to that effect must accompany the deposit. Also a

* This advertisement may be in print, and fixed to the body of the Memorial.

separate list of the local and road authorities affected by any application relating to the use of steam or other mechanical power on authorised tramways, or to an extension of time or abandonment; together with a copy of any notice served under Rule VII.

(3) *Copy of Street Notice.*—A certified copy of the notice which is required by Rule V. to be posted in the streets in October or November next before the application.

(4) *List of Frontagers and Copy of Notice.*—In all cases where for a distance of 30 feet or upwards it is proposed that a less space than nine feet six inches shall intervene between the outside of the footpath on either side of the road and the nearest rail of the tramway, or a less space than ten feet six inches if it is intended to run on the tramway carriages or trucks adapted for use upon railways, a complete list of the owners or reputed owners, lessees or reputed lessees, and occupiers of all houses, shops, or warehouses abutting upon any part of the highway, where such less space is proposed, together with a certified copy of the notice which was served on them on or before the 15th of December, as required by Rule IX. (The list should be so prepared as to show distinctly and separately every length of street or road where for a distance of thirty feet or upwards such less space is proposed, and in respect of every such length of street or road it should indicate in parallel columns the name of the street, the name or number of the house, shop, or warehouse, and the names of the owner or reputed owner, the lessee or reputed lessee, and of the occupier.)

(5) *Description of Land.*—A description of the land (if any), which the promoters propose to purchase for the construction of the tramway. (The contracts for the purchase of all the lands required must be produced at the time of proving compliance with the Act and these Rules.)

(6) *Memorandum of Association, etc.*—A list of every Provisional Order or Act of Parliament (if any) of the promoters; and where the promoters are a company incorporated under the Companies' Act, 1862, a printed copy of the Memorandum of Association, Articles of Association, and any registered special resolution of the company; and in the case of a company incorporated in any other manner, a copy of every deed or instrument of settlement or incorporation.

(7) *Fee.*—A fee of £35, by cheque, payable to "An Assistant Secretary of the Board of Trade." (This fee will not be necessarily taken to cover the cost of inquiries or other matters arising out of the application. With respect to costs in such matter, security must be given from time to time by the promoters as the Board of Trade may require.)

Draft Provisional Order.

Rule XVI. The following rules must be observed in regard to the draft Provisional Order:—

(1) The draft Provisional Order must be deposited in triplicate, and be printed *on one side only of the page*, so as to leave the back of the page blank, and any schedule annexed must begin a new page.

(2) The draft Provisional Order must describe where each tramway is to commence and terminate, and must state the streets and roads along which it is to pass, and the total length of the double and single portions respectively of such tramway in miles, furlongs, chains, and decimals of a chain.

(3) Each double and single portion of such tramway, with its commencement and termination, must also be described. (This can be done by stating that each line or branch line will be double or single throughout, except at certain specified places where it will be single or double.)

(4) Every passing-place must be described as a double line in accordance with the

Standing Order of the House of Lords, which provides that "*two lines oj tramway running side by side shall be described as a double line.*"

(5) In cases where the promoters are individuals, their addresses as well as names should be inserted in the draft order.

(6) The names and addresses of the agents for the Provisional Order must be printed on the outside of the draft Order, and there mnst be a notice at the end of it stating that objections are to be addressed to the Assistant Secretary of the Railway Department of the Board of Trade on or before the 15th January next ensuing, that copies of objections must at the same time be sent to the promoters, and that, in forwarding to the Board of Trade such objections, the objectors or their agents should state that a copy of the same has been sent to the promoters or their agents.

PROOFS OF COMPLIANCE WITH THE ACT AND RULES.

Rule XVII. The agent should be prepared to prove compliance with the provisions of the Act and these Rules by the *15th January, and all such proofs must be completed on or before 22nd February.* Six days' notice will be given of the day and hour at which the agents are to attend for the purpose at the Board of Trade, and printed forms of proof will accompany the notice. These forms should be filled up by the agents, and brought with the requisite documents to the Department at the time fixed for proving compliance.

If any local or road authority, or any railway, tramway, or canal company, or any other company, body, or person, desire to have any clauses or other amendments inserted in the Order, they must deliver the same to the agents for the Order, and also to the Board of Trade, not later than the *8th February.*

On or before the 22nd February the agents must deposit at the Board of Trade a filled-up draft printed Order (in duplicate) containing in manuscript all such clauses or other amendments as have been agreed upon.

If any of the clauses or other amendments which have been delivered to the agents are not settled with the consent of both parties, the agents must, so far as they can, on or before the 22nd February, show what are the amendments, if any, which each party would be willing to accept.

After the 22nd February no further proposals for clauses will be entertained by the Board of Trade.

DEPOSIT AND ADVERTISEMENT OF ORDER AS MADE.

"Section 13.—When a Provisional Order has been made as aforesaid and delivered to the promoters, the promoters shall forthwith publish the same by deposit and advertisement, according to the regulations contained in Part IV. of the Schedule (B) to this Act."

"*Schedule B. Part IV.*

"(1) The promoters are to deposit printed copies of the Provisional Order, when settled and made for public inspection, in the offices of clerks of the peace and sheriff clerks, where the documents required to be deposited by them under Part II. of this Schedule were deposited.

"(2) They are also to deposit a sufficient number of such printed copies at the office named in that behalf in the advertisement, such copies to be there furnished to all persons applying for them at the price of not more than* each.

* The Board of Trade consider that the price to be here inserted should not be more than one shilling.

"(3) They are also to publish the Provisional Order as an advertisement once in the local newspaper in which the original advertisement of the intended application was published, or, in case the same shall no longer be published, in some other newspaper published in the district."

(*Note.*—Section 14 of the Act requires that the Order as made shall be deposited and advertised *not later* than the 25th April.)

Rule XVIII. *Deposit of Amended Plan and Section.*—Should any alteration of the plan and section originally deposited for the purposes of the Order be made, with the approval of the Board of Trade, before the Order is granted, a copy of such plan and section (or of so much thereof as may be necessary) showing such alteration, must, before the Order is introduced into a Confirmation Bill, be deposited by the promoters for public inspection :—

In England, in the office of the clerk of the peace for every county, riding, or division, and of the parish clerk of every parish, and the office of the Local Authority of every district, affected by such alteration ; and

In Scotland, in the office of the principal sheriff clerk for every county, district, or division affected by such alteration.

Copies of such documents are at the same time to be deposited at the office of the Board of Trade, in the office of the clerk of the Parliaments, and at the Private Bill Office.

Rule XIX. When a Provisional Order has been made, and before it is introduced into the Confirmation Bill, the promoters will be required to submit to the Board of Trade the following proofs, viz. :—

(1) The receipt of the clerk of the peace or sheriff clerk, or proof by affidavit of the deposit of the Order with such officer, as required by Part IV. of Schedule B to the Act.

(2) A copy of the local newspaper containing the advertisement of the Order. This advertisement must have a short heading stating that the Order has been made by the Board of Trade under the Tramways Act, 1870, previous to its being introduced into a Confirmation Bill, and must also state the name of the office where printed copies of the Order can be obtained.

(3) Proof must also be given that the advertised Order is a correct copy of the Order delivered by the Board of Trade to be advertised, that it was inserted in the newspaper in which the original advertisement of the application for the Order was published, and that a sufficient number of printed copies of the Order were deposited for sale at the office named in the original advertisement, with a statement of the price for which they may be obtained.

(4) Receipts of proof by affidavit of the deposit of amended plans, as required by Rule XVIII.

Printed forms for these proofs will be furnished by the Board of Trade when the Order is sent to the promoters to be advertised, and one of these forms must be filled up by the promoters, or brought or forwarded to the Department with the requisite document, *as soon as possible* after the advertisement and deposit has been made.

Deposit of Money, Penalty for Non-Completion of Tramways, and Release of Deposit.

Rule XX. *Deposit of Money in the Chancery Division under Section 12 of Act.*—After the Provisional Order is ready, and before the same is introduced by the Board of Trade into a Confirming Bill, the promoters (unless they are a local authority), shall, if they are not possessed of a tramway already opened for public traffic, which had during the year last past paid dividends on their ordinary share capital, pay as a deposit a sum of money not less than five per centum on the amount of the estimate of the expense of the construction of the tramway as follows, namely :

Where the tramway or any part thereof will be situate in England: to the account of the Paymaster-General for and on behalf of the Supreme Court of Judicature in England, to the credit of the particular tramway.

Where the tramway will be situate wholly in Scotland: either to the account of the Paymaster-General, for and on behalf of the Supreme Court of Judicature in England in manner aforesaid, or (at the option of the promoters) into a bank in Scotland established by Act of Parliament or Royal Charter, in the name of, and with the privity of the Queen's Remembrancer of the Court of Exchequer in Scotland, *ex parte* the particular tramway.

The Board of Trade may issue their warrant to the promoters for such payment into court, which warrant shall be a sufficient authority for the *persons* therein named, not exceeding five in number, or the majority or survivors of them, to pay the money therein mentioned to the account of the Paymaster-General for and on behalf of the Supreme Court of Judicature in England, or into the bank therein mentioned, in the name and with the privity of the officer therein mentioned, if any, and for that officer to issue directions to such bank to receive the same, to be placed to his account there according to the method (prescribed by statute, or general rules, or orders of court, or otherwise) for the time being in force respecting the payment of money into the said courts respectively, and without fee or reward.

Provided, that in lieu, wholly or in part, of the payment of money, the promoters may bring into court as a deposit an equivalent sum of bank annuities, or of any stocks, funds, or securities on which cash under the control of the respective courts is for the time being permitted to be invested, or of exchequer bills (the value thereof being taken at the price at which the promoters originally purchased the same, as appearing by the broker's certificate of that purchase); and in that case the Board of Trade shall vary their warrant accordingly, by directing the transfer or deposit of such amount of stocks, funds, securities, or exchequer bills by the persons therein named.

Where money is so paid into the Supreme Court of Judicature, the court may, on the application of the persons named in the warrant of the Board of Trade, or of the majority or survivors of them, order that the same be invested in such stocks, funds, or securities as the applicants desire and the court thinks fit.

In the subsequent provisions of these Rules, the term "the deposit fund" means the money deposited, or the stocks, funds, or securities in which the same is invested, or the bank annuities, stocks, funds, securities, or exchequer bills transferred or deposited, as the case may be; and the term "the depositors" means the persons named in the warrant of the Board of Trade authorising the deposit, or the majority or survivors of those persons, their executors administrators, or assigns.

Rule XXI. *Penalty for Non-completion of Tramways.*—If the promoters empowered by the order to make the tramway are possessed of a tramway already opened for public traffic, and which has during the year last past paid dividends on their ordinary share capital, no deposit will be required; but if such promoters (unless they are a local authority) do not, within the time in the Order prescribed, or within the time as prolonged by the special direction of the Board of Trade under section 18 of the Tramways Act, 1870, or if none is prescribed, or if the time has not been prolonged as aforesaid, then within two years from the passing of the Act confirming the Order, complete the tramway authorised by the Order, they will be liable to a penalty of £50 a day for every day after the expiration of the period so limited, until the said tramway is completed and opened for public traffic, or until the sum received in respect of such penalty shall amount to five per cent. on the estimated cost of the works; and the said penalty may be applied for by any road authority claiming to be compensated in accordance with the provisions of Rule XXII., and in the same manner as the

penalty provided in the third section of the Act, 17 and 18 Vict., c. 31, known as "The Railway and Canal Traffic Act, 1854," and every sum of money recovered by way of such penalty as aforesaid, shall be paid under the warrant or order of such court or judge as is specified in the said third section of the Act 17 and 18 Vict., c. 31, to an account opened or to be opened in the name and with the privity of the Paymaster-General for and on behalf of the Supreme Court of Judicature in England and the Queen's Remembrancer of the Court of Exchequer in Scotland (according as the tramway is situate in England or Scotland), in the bank named in such Order, and shall not be paid thereout, except as provided by Rule XXII.; but no penalty will accrue in respect of any time during which it shall appear, by a certificate to be obtained from the Board of Trade, that the promoters were prevented from completing or opening such tramway by unforeseen accident or circumstances beyond their control. Provided that the want of sufficient funds will not be held to be a circumstance beyond their control.

Rule XXII. *Application oj Deposit.*—If the promoters empowered by the Order to make the tramway do not, within the time in the Order prescribed, or within the time as prolonged by the special direction of the Board of Trade under section 18 of the Tramways Act, 1870, and if none is prescribed, or if the time has not been prolonged as aforesaid, then within two years from the passing of the Act confirming the Order, complete the tramway, and open it for public traffic, then and in every case the deposit fund, or so much thereof as shall not have been repaid to the depositors (or any sum of money recovered by way of such penalty as aforesaid), shall be applicable, and after due notice in the *London* or *Edinburgh Gazette*, as the case may require, shall be applied towards compensating all road authorities for the expense incurred by them in taking up any tramway or materials connected therewith placed by the promoters in or on any road vested in or maintainable by such road authorities respectively, and in making good all damage caused to such roads by the construction or abandonment of such tramway, and for which expense or damage no compensation or inadequate compensation shall have been paid, and shall be distributed in satisfaction of such compensation in such manner and in such proportions as to the Supreme Court of Judicature in England, or Court of Exchequer in Scotland, as the case may be, may seem fit; and if no such compensation shall be payable, or if a portion of the said deposit fund (or of the sum or sums of money recovered by way of penalty aforesaid) shall have been found sufficient to satisfy all just claims in respect of such compensation, then the said deposit fund (or the sum or sums of money received by way of penalty aforesaid), or such portion of it as may not be required as aforesaid, shall in the discretion of the court, if the promoters are a company and a receiver has been appointed, or if such company is insolvent and has been ordered to be wound up, be paid or transferred to such receiver, or to the liquidator or liquidators of the company, or be applied in the discretion of the court as part of the assets of the company, for the benefit of the creditors thereof. Subject to such application as aforesaid, the deposit fund may be repaid or re-transferred to the depositors or as they shall direct.

Rule XXIII. *Release of Deposit.*—The court in which the deposit is made shall, on the application of the depositors, order the deposit fund to be paid or transferred to the applicants, or as they shall direct, if, within the time by the Order prescribed, or within the time prolonged by the special direction of the Board of Trade under section 18 of the Tramways Act, 1870, and if none is prescribed, or if the time has not been prolonged as aforesaid, then within two years from the passing of the Act confirming the Order, the promoters thereby empowered to make the tramway, complete it, and open it for public traffic after inspection by an inspector appointed by the Board of Trade, and upon a certificate of the Board of Trade that the tramway is fit for public traffic, as provided by Rule XXV. Provided that, if within such time as aforesaid any portion of a line of tramway authorised by an Order is opened for

public traffic, after such inspection as aforesaid, and on such certificate under Rule XXV. as aforesaid, then on the production of a certificate of the Board of Trade, specifying the length of the portion of the tramway opened as aforesaid, and the portion of the deposit fund which bears to the whole of the deposit fund the same proportion as the length of the tramway so opened bears to the entire length of the tramway authorised by the Order, the court in which the deposit is made shall, on the application of the depositors, order the said portion of the deposit fund so specified in such certificate as aforesaid to be paid or transferred to them, or as they shall direct

Rule XXIV. *Miscellaneous as to Deposits.*—The depositors shall be entitled to receive payment of any interest or dividends from time to time accruing on the deposit fund while in court; and the court in which the deposit is made from time to time, on the application of the depositors, shall make such order as seems fit respecting the payment of the interest or dividends accordingly.

If either House of Parliament refuse to confirm any Provisional Order in respect whereof a deposit has been made under these rules, or authorize a portion only of any tramway comprised in such Order, or if any such Provisional Order be withdrawn before the same is confirmed by Parliament, the court shall, upon production of a certificate of the Board of Trade, order the deposit fund or a proportionate part thereof, as the case may be, to be paid to the depositors, or as they shall direct.

The issuing in any case of any warrant or certificate relating to deposit or to the deposit fund, or any error in any such warrant or certificate, or in relation thereto, shall not make the Board of Trade, or the person signing the warrant or certificate on their behalf, in any manner liable for or in respect of the deposit fund, or the interest of or dividends on the same, or any part thereof respectively.

Any application under these Rules to the Supreme Court of Judicature shall be made in a summary manner by summons at Chambers.

Opening of Tramways.

Rule XXV. The promoters shall give to the Board of Trade at least fourteen days' notice in writing of their intention to open any tramway, or portion of a tramway, and such tramway or portion of tramway shall not be opened for public traffic until an inspector appointed by the Board of Trade has inspected the same, and the Board of Trade has certified that it is fit for such traffic. The above-mentioned notice should be accompanied by the following documents, viz. :—

(1) A copy of the Act of Provisional Order authorising the construction of the tramways.

(2) A copy of tracing of so much of the deposited plans and sections as relates to the portion of tramway proposed to be opened, distinguishing between double and single line, and showing in red ink any variation therefrom in the tramways as constructed.

(3) A list of the local and road authorities concerned.

(4) A diagram of the lines submitted for inspection on a scale of about two inches to a mile.

Prolongation of Time for the Commencement or Completion of Works.

The Board of Trade under the powers conferred upon them by section 18 of the Tramways Act, 1870, have made the following rules with respect to applications for a prolongation of time for the commencement or the completion of the works authorised by any order made under the above-named Act:—

1. The application should be in the form of a memorial setting forth the grouuds on which the application is made, and must be made *at least one month before* the expiration of the time prescribed for the commencement or the completion of the work, as the case may be.

2. The promoters of any tramway undertaking authorised by any Order, who intend to apply to the Board of Trade for a prolongation of the time limited for the commencement or the completion of the works authorised by such Order, shall publish by advertisement, once at least in each of two successive weeks, in some one and the same newspaper published in the district affected by such Order, a notice of their intention to apply to the Board of Trade for a prolongation of time.

3. The notice must state the period to which it is proposed to prolong the time limited for the commencement or the completion of the works, as the case may be, and must contain a notification that all persons desirous of making any representation to the Board of Trade, or of bringing before them any objection respecting the application, may do so by letter addressed to the Assistant Secretary (Railway Department), Board of Trade, on or before the day to be named in the advertisement, being not less than twenty-one days from the date of the first publication of the advertisement, and that copies of their representations or objections should at the same time be sent to the promoters.

4. A similar notice must be delivered to every local and road authority *before* the second publication of the notice. Copies of newspapers containing the notice, and a statement that a copy of it has been duly served on the local and road authorities as required by these Rules, must be sent to the Board of Trade with the application.

5. Before the Board of Trade comply with the application, they will impose such conditions (if any) as they think fit.

III. Forms of Byelaws and Regulations issued by the Board of Trade.

(i) For a Local Authority.
(ii) For a Tramway Company.
(iii) With respect to the use of Steam Power.
(iv) With respect to Electric Traction.

(I) Byelaws and Regulations made by the Local Authority, under Section 46 of the Tramways Act, 1870.

1. For the purpose of these Byelaws and Regulations, the term "car" shall mean any (engine or) carriage using any tramway laid down within the said (borough), and the terms "driver" and "conductor" shall respectively mean the driver and conductor, or other person having charge of (an engine or) car.

2. The driver of every car shall cause the same to be driven at a speed of not less than (four) miles an hour on the average, and not exceeding eight miles an hour.

3. The driver of every car shall so drive the same that it shall not follow a preceding car at a less distance than* yards.

4. Subject to the requirements of Byelaws Nos. 3 and 5, the driver or conductor of a car shall stop the same for the purpose of setting down or taking up passengers, when required by any passenger desiring to leave the car, or by any person desirous of travelling by the car, for whom there is room, and to whose admission no valid objection can be made: provided that nothing in this Byelaw shall require a car to be stopped on any gradient steeper than 1 in 25.

5. Except at a passing place or terminus, no car shall be stopped at the intersection or junction of two or more streets or roads, nor within (ten) yards of a car on an adjoining line of rails.

* This distance should be not less than 10 nor more than 150 yards.

6. The driver of a car, on coming in sight of a vehicle standing or travelling on any part of the road so as not to leave sufficient space for the car to pass, shall sound his bell or whistle as a warning to the person in charge of such vehicle, and that person shall, with reasonable dispatch, cause such vehicle to be removed so as not to obstruct the car.

7. No person shall in any way wilfully impede or interfere with the traffic on the tramways, nor shall any driver or conductor needlessly cause interruption to the ordinary road traffic.

8. Every driver, conductor, or other person offending against any of these byelaws and regulations shall be liable to a penalty not exceeding forty shillings for each offence, and not exceeding for any continuing offence ten shillings for every day during which the offence continues.

(*Here insert any Byelaws to meet special cases.*)

9. These byelaws shall come into force on the day of , 18 .

The Common Seal of the said Mayor, Aldermen, and Burgesses, affixed by order of the Council of the said borough at a meeting of such Council held on the day of , in the presence of

L.S. by ...., Mayor.
...................., Town Clerk.

I hereby certify that a true copy of the foregoing byelaws and regulations has, in accordance with the provisions of section 46 of the Tramways Act, 1870, been laid before the Board of Trade not less than two calendar months before such byelaws and regulations have not been disallowed by the Board of Trade within the said two calendar months.

An Assistant Secretary to the Board of Trade.
day of , 189 .

(II.).—BYELAWS AND REGULATIONS MADE BY THE COMPANY UNDER THE POWERS CONFERRED ON THE COMPANY BY THE TRAMWAYS ACT, 1870.

1. The byelaws and regulations hereinafter set forth shall extend and apply to all carriages of the company, and to all places with respect to which the company have power to make byelaws or regulations.

2. Every passenger shall enter or depart from a carriage by the hindermost or conductor's platform, and not otherwise.

3. No passenger shall smoke inside any carriage.

4. No passenger or other person shall, while travelling in or upon any carriage, play or perform upon any musical instrument.

5. A person in a state of intoxication shall not be allowed to enter or mount upon any carriage, and if found in or upon any carriage shall be immediately removed by or under the direction of the conductor.

6. No person shall swear or use obscene or offensive language whilst in or upon any carriage, or commit any nuisance in or upon or against any carriage, or wilfully interfere with the comfort of any passenger.

7. No person shall wilfully cut, tear, soil, or damage the cushions or the linings, or remove or deface any number plate, printed or other notice, in or on the carriage, or break or scratch any window of or otherwise wilfully damage any carriage. Any person acting in contravention of this regulation shall be liable to the penalty prescribed by these byelaws and regulations, in addition to the liability to pay the amount of any damage done.

8. A person whose dress or clothing might, in the opinion of the conductor of a carriage, soil or injure the linings or cushions of the carriage, or the dress or clothing of any passenger, or a person who, in the opinion of the conductor, might for any other reason be offensive to passengers, shall not be entitled to enter or remain in the interior of any carriage after having been requested not to do so by the conductor; and if found in the interior of any carriage shall, on request of the conductor, leave the interior of the carriage upon the fare, if previously paid, being returned.

9. Each passenger shall, upon demand, pay to the conductor or other duly authorised officer of the company the fare legally demandable for the journey.

10. Each person shall show his ticket (if any) when required so to do to the conductor or any duly authorised servant of the company, and shall also, when required so to do, either deliver up his ticket or pay the fare legally demandable for the distance travelled over by such passenger.

11. A passenger not being an artisan, mechanic, or daily labourer, within the true intent and meaning of the Acts of Parliament relating to the company, shall not use or attempt to use any ticket intended only for such artisans, mechanics, or daily labourers.

12. Personal or other luggage (including the tools of artisans, mechanics, and daily labourers) shall, unless otherwise permitted by the conductor, be placed on the front or driver's platform, and not in the interior or on the roof of any carriage.

13. No passenger or other person not being a servant of the Company shall be permitted to travel on the steps or platforms of any carriage, or stand either on the roof or in the interior, or sit on the outside rail on the roof of any carriage, and shall cease to do so immediately on request by the conductor.

14. No person, except a passenger or intending passenger, shall enter or mount any carriage, and no person shall hold or hang on by or to any part of any carriage, or travel therein otherwise than on a seat provided for passengers.

15. When any carriage contains the full number of passengers which it is licensed to contain, no additional person shall enter, mount, or remain in or on any such carriage when warned by the conductor not to do so.

16. When a carriage contains the full licensed number of passengers, a notice to that effect shall be placed in conspicuous letters and in a conspicuous position on the carriage.

17. The conductor shall not permit any passenger beyond the licensed number to enter or mount or remain in or upon any part of a carriage.

18. No person shall enter, mount, or leave, or attempt to enter, mount, or leave any carriage whilst in motion.

19. No dog or other animal shall be allowed in or on any carriage, except by the permission of the conductor, nor in any case in which the conveyance of such dog or animal might be offensive or an annoyance to passengers. No person shall take a dog or other animal into any carriage after having been requested not to do so by the conductor. Any dog or other animal taken into or on any carriage in breach of this regulation shall be removed by the person in charge of such dog or other animal from the carriage immediately upon request by the conductor, and in default of compliance with such request may be removed by or under the direction of the conductor.

20. No person shall travel in or on any carriage of the Company with loaded firearms.

21. No passenger shall wilfully obstruct or impede any officer or servant of the Company in the execution of his duty upon or in connection with any carriage or tramway of the Company.

22. The conductor of each carriage shall enforce or prevent the breach of these byelaws and regulations to the best of his ability.

23. Any person offending against or committing a breach of any of these byelaws and regulations shall be liable to a penalty not exceeding Forty Shillings.

24. The expression "conductor" shall include any officer or servant in the employment of the Company and having charge of a carriage.

25. There shall be placed, and kept placed, in a conspicuous position inside of each carriage in use a printed copy of these byelaws and regulations.

26. These byelaws shall come into force on the day of , 189 .

Secretary of the Company.

I hereby certify that a true copy of the foregoing byelaws and regulations has, in accordance with the provisions of s. 46 of the Tramways Act, 1870, been laid before the Board of Trade not less than two calendar months before such byelaws and regulations came into operation, and that such byelaws and regulations have not been disallowed by the Board of Trade within the said two calendar months.

An Assistant Secretary to the Board of Trade.
189 .

(III.)—Regulations and Byelaws made by the Board of Trade with respect to the Use of Steam (or any Mechanical) Power on Tramways.

The Board of Trade, under and by virtue of the powers conferred upon them in this behalf, do hereby order that the following regulations for securing to the public reasonable protection against danger in the exercise of the powers conferred by Parliament with respect to the use of steam (or any mechanical) power on all or any of the tramways on which the use of such power has been authorised by the (hereinafter called "the tramways") be (added to) or (substituted for) all other regulations in this behalf contained in any Tramway Act or Tramway Order confirmed by Act of Parliament, or in any Order of the Board of Trade heretofore made thereunder:

And the Board of Trade do also hereby make the following byelaws, or rescind and annul all byelaws heretofore made by them with regard to all or any of the tramways aforesaid, and do hereby make the following byelaws, or in addition to the byelaws already made by them with regard to all or any of such tramways.

Regulations.—I. The engine or engines to be used on the tramways shall comply with the following requirements, that is to say:—

(*a*) Each coupled wheel shall be fitted with a break block, which can be applied by a screw or treadle or by other means, and also by steam.

(*b*) A governor (which cannot be tampered with by the driver) shall be attached to each engine, and shall be so arranged that at any time when the engine exceeds a speed of (ten) miles an hour it shall cause the steam to be shut off and the brake applied.

(*c*) Each engine shall be numbered, and the number shall be shown in a conspicuous part thereof.

(*d*) Each engine shall be fitted with an indicator by means of which the speed is shown; with a suitable fender to push aside obstructions; and with a special bell (or whistle, or other apparatus) to be sounded as a warning when necessary.

(*e*) Arrangements shall be made enabling the driver to command the fullest possible view of the road before him.

(*f*) Each engine shall be free from noise produced by blast and from the clatter of machinery such as to constitute any reasonable ground of complaint either to the passengers or to the public; the machinery shall be concealed from view at all points above four inches from the level of the rails, and all fire used on such engines shall be concealed from view.

II. Every carriage used on the tramways shall be so constructed as to provide for the safety of passengers, and for their safe entrance to, exit from, and accommodation in such carriages, and for their protection from the machinery of any engine used for drawing or propelling such carriages.

III. The Board of Trade and their officers may, from time to time, and shall, on the application of the local authority of any of the districts through which the said tramways pass, inspect such engines or carriages used on the tramways and the machinery therein, and may, whenever they think fit, prohibit the use on the tramways of any of them which in their opinion are not safe for use.

IV. The speed at which such engines and carriages shall be driven or propelled along the tramways shall not exceed the rate of (*eight*) miles an hour, and the speed at which such engines and carriages shall pass through facing-points, whether fixed or movable, shall not exceed the rate of *four* miles an hour.

V. The engines and carriages shall be connected by double couplings.

VI. Every engine running on the tramways shall carry a lamp or lamps placed in a conspicuous position in the front of the engine, and such lamp or lamps shall be kept lighted from sunset to sunrise, or when there is a fog, and shall show when lighted a bright coloured light.

(*Here to follow any special Regulations that may be necessary.*)

VII. The speed of the engines and carriages shall not exceed the rate of *four* miles an hour at the following places:—

Penalty.—Note.—Any Company or person using steam (or any mechanical) power on the tramways contrary to any of the above Regulations is for every such offence subject to a penalty not exceeding ten pounds, and also in the case of a continuing offence to a further penalty not exceeding five pounds for every day after the first, during which such offence continues.

Byelaws.—I. The special bell (or whistle, or other apparatus) shall be sounded by the driver of the engine from time to time when it is necessary as a warning.

II. No smoke or steam shall be emitted from the engines so as to constitute any reasonable ground of complaint to passengers or to the public.

III. Whenever it is necessary to avoid impending danger, the engine shall be brought to a standstill.

IV. The entrance to and exit from the carriages shall be by the hindermost or conductor's platform.

(*Here to follow any special Byelaws that may be necessary.*)

V. The engines and carriages shall be brought to a standstill immediately before reaching the following points:

VI. A printed copy of the foregoing regulations and byelaws, and of all additional regulations and byelaws hereafter made, shall be placed, and kept placed, in a conspicuous position inside of each carriage in use on the tramways.

Penalty.—Note.—Any person or corporation offending against or committing a breach of any of these byelaws is liable to a penalty not exceeding forty shillings.

The provisions of the Tramways Act, 1870, with respect to recovery of penalties is applicable to the penalties for the breach of these regulations or byelaws.

Signed, by order of the Board of Trade, this day of , 189 .

An Assistant Secretary to the Board of Trade.

LIGHT RAILWAYS ACT, 1896.

(59 and 60 Vict. Ch. 48.)

AN ACT TO FACILITATE THE CONSTRUCTION OF LIGHT RAILWAYS IN GREAT BRITAIN. 14TH AUGUST, 1896.

Be it enacted by the Queen's most Excellent Majesty, by and with the advice and consent of the Lords Spiritual and Temporal, and Commons, in this present Parliament assembled, and by the authority of the same, as follows:—

ESTABLISHMENT OF LIGHT RAILWAY COMMISSION.

1.—(1) For the purpose of facilitating the construction and working of light railways in Great Britain, there shall be established a commission, consisting of three commissioners, to be styled the Light Railway Commissioners, and to be appointed by the President of the Board of Trade.

(2) It shall be the duty of the Light Railway Commissioners to carry this Act into effect, and to offer, so far as they are able, every facility for considering and maturing proposals to construct light railways.

(3) If a vacancy occurs in the office of any of the Light Railway Commissioners by reason of death, resignation, incapacity, or otherwise, the President of the Board of Trade may appoint some other person to fill the vacancy, and so from time to time as occasion may require.

(4) There shall be paid to one of the Commissioners such salary, not exceeding one thousand pounds a year, as the Treasury may direct.

(5) The Board of Trade may, with the consent of the Treasury as to number and remuneration, appoint and employ such number of officers and persons as they think necessary for the purpose of the execution of the duties of the Light Railway Commissioners under this Act, and may remove any officer or person so appointed or employed.

(6) The said salary and remuneration, and all expenses of the Light Railway Commissioners incurred with the sanction of the Treasury in the execution of this Act, shall, except so far as provision is made for their payment by or under this Act, be paid out of moneys provided by Parliament.

(7) The Commissioners may act by any two of their number.

(8) The powers of the Light Railway Commissioners shall, unless continued by Parliament, cease on the thirty-first day of December one thousand nine hundred and one.

APPLICATION FOR ORDERS AUTHORISING LIGHT RAILWAYS.

2.—An application for an order authorising a light railway under this Act shall be made to the Light Railway Commissioners, and may be made—

(*a*) by the council of any county, borough, or district, through any part of which the proposed railway is to pass; or

(*b*) by any individual, corporation, or company; or

(*c*) jointly by any such councils, individuals, corporations, or companies.

POWERS OF LOCAL AUTHORITIES UNDER ORDER.

3.—(1) The council of any county, borough, or district may, if authorised by an order under this Act—

(*a*) Undertake themselves to construct and work, or to contract for the construction or working of, the light railway authorised;

(*b*) advance to a light railway company, either by way of loan or as part of the share capital of the company, or partly in one way and partly in the other, any amount authorised by the order;

(*c*) join any other council or any person or body of persons in doing any of the things above mentioned; and

(*d*) do any such act incidental to any of the things above mentioned as may be authorised by the order.

(2) Provided that—

(*a*) An order authorising a council to undertake to construct and work or to contract for the construction or working of a light railway, or to advance money to a light railway company, shall not be made except on an application by the council made in pursuance of a special resolution passed in manner directed by the First Schedule to this Act; and

(*b*) a council shall not construct or work or contract for the construction or working of any light railway wholly or partly outside their area, or advance any money for the purpose of any such railway, except jointly with the council of the outside area, or on proof to the satisfaction of the Board of Trade that such construction, working, or advance is expedient in the interests of the area of the first-mentioned council, and in the event of their being authorised so to do their expenditure shall be so limited by the order as not to exceed such amount as will, in the opinion of the Board of Trade, bear due proportion to the benefit which may be expected to accrue to their area from the construction or working of the railway.

LOANS BY TREASURY.

4.—(1) Where the council of any county, borough, or district, have advanced or agreed to advance any sum to a light railway company, the Treasury may also agree to make an advance to the company, by lending them any sum not exceeding one-quarter of the total amount required for the purpose of the light railway and not exceeding the amount for the time being advanced by the council.

Provided that the Treasury shall not advance money to a light railway company under this section, unless at least one-half of the total amount required for the purpose of the light railway is provided by means of share capital, and at least one-half of that share capital has been subscribed and paid up by persons other than local authorities.

(2) Any loan under this section shall bear interest at such rate not less than three pounds two shillings and sixpence per centum per annum as the Treasury may from time to time authorise as being in their opinion sufficient to enable such loans to be made without loss to the Exchequer, and shall be advanced on such conditions as the Treasury determine.

(3) Where the Treasury advance money to a light railway company under this section, and the advance by the council to the company is made in whole or part by means of a loan, the loan by the Treasury under this section shall rank pari passu with the loan by the council.

SPECIAL ADVANCES BY TREASURY.

5.—(1) Where it is certified to the Treasury by the Board of Agriculture that the making of any light railway under this Act would benefit agriculture in any district, or by the Board of Trade that by the making of any such railway a necessary means of communication would be established between a fishing harbour or fishing village and a market, or that such railway is necessary for the development of or maintenance of some definite industry, but that owing to the exceptional circumstances of the district the railway would not be constructed without special assistance from the State, and the Treasury are satisfied that a railway company existing at the time will construct and work the railway if an advance is made by the Treasury under this section, the Treasury may, subject to the limitation of this Act as to the amount to be expended for the purpose of special advances, agree that the railway be aided out of public money by a special advance under this section.

Provided that—

(*a*) the Treasury shall not make any such special advance unless they are satisfied that landowners, local authorities, and other persons locally interested have by the free grant of land or otherwise given all reasonable assistance and facilities in their power for the construction of the railway; and

(*b*) a special advance shall not in any case exceed such portion not exceeding one-half of the total amount required for the construction of the railway as may be prescribed by rules to be made by the Treasury under this Act; and

(*c*) where the Treasury agree to make any such special advance as a free grant, the order authorising the railway may make provision as regards any parish that, during a period not exceeding ten years to be fixed by the order, so much of the railway as is in that parish shall not be assessed to any local rate at a higher value than that at which the land occupied by the railway would have been assessed if it had remained in the condition in which it was immediately before it was acquired for the purpose of the railway, but before such provision is made in any order the local and rating authorities of every such parish shall be informed of the intention to insert such provision, and shall be entitled to be heard. The order may authorise the Board of Trade to extend any such period.

(2) A special advance under this section may be a free grant or a loan, or partly a free grant and partly a loan.

(3) Any free grant or loan for a special advance under this section shall be made on such conditions and at such rate of interest as the Treasury direct.

LIMITATION ON AMOUNT OF ADVANCE AND PROVISION OF MONEY BY NATIONAL DEBT COMMISSIONERS.

6.—(1) The total amount advanced by the Treasury under this Act shall not at any one time exceed one million pounds, of which a sum not exceeding two hundred and fifty thousand pounds may be expended for the purpose of special advances under this Act.

(2) The National Debt Commissioners may lend to the Treasury, and the Treasury may borrow from the National Debt Commissioners, such money as may be required for the purpose of advances by the Treasury under this Act, on such terms as to interest, sinking fund, and period of repayment (not exceeding thirty years from the date of the loan) as may be agreed on between the National Debt Commissioners and the Treasury.

(3) The sums so lent by the National Debt Commissioners shall be repaid out of money provided by Parliament for the purpose, and if and so far as that money is insufficient shall be charged on, and payable out of, the Consolidated Fund, or the growing produce thereof.

CONSIDERATION OF APPLICATION BY LIGHT RAILWAY COMMISSIONERS.

7.—(1) Where an application for authorising a light railway under this Act is made to the Light Railway Commissioners, those Commissioners shall, in the first instance, satisfy themselves that all reasonable steps have been taken for consulting the local authorities, including road authorities, through whose areas the railway is intended to pass, and the owners and occupiers of the land it is proposed to take, and for giving public notice of the application, and shall also themselves by local inquiry and such other means as they think necessary possess themselves of all such information as they may consider material or useful for determining the expediency of granting the application.

(2) The applicants shall satisfy the Commissioners that they have—

(*a*) Published once at least in each of two consecutive weeks, in some newspaper circulating in the area or some part of the area through which the light railway is to pass, an advertisement describing shortly the land proposed to be taken and the purpose for which it is proposed to be taken, naming a place where a plan of the proposed works and the lands to be taken, and a book of reference to the plan, may be seen at all reasonable hours, and stating the quantity of land required; and

(*b*) served notice in the prescribed manner on every reputed owner, lessee, and occupier of any land intended to be taken, describing in each case the land intended to be taken, and inquiring whether the person so served assents to or dissents from the taking of his land, and requesting him to state any objections he may have to his land being taken.

The plan and book of reference shall be in the prescribed form, and for the purposes of this section the expression "prescribed" shall mean prescribed by rules made under this Act.

(3) The Commissioners shall before deciding on an application give full opportunity for any objections to the application to be laid before them, and shall consider all such objections, whether made formally or informally.

(4) If after consideration the Commissioners think that the application should be granted, they shall settle any draft order submitted to them by the applicants for authorising the railway, and see that all such matters (including provisions for the safety of the public and particulars of the land proposed to be taken) are inserted therein, as they think necessary for the proper construction and working of the railway.

(5) The order of the Light Railway Commissioners shall be provisional only, and shall have no effect until confirmed by the Board of Trade in manner provided by this Act.

(6) Where an application for a light railway has been refused by the Light Railway Commissioners, the applicants, if the council of any county, borough, or district, may appeal against such refusal to the Board of Trade, who may, at any time, if they think fit, remit the application or any portion thereof to the said Commissioners for further consideration with or without special instructions.

SUBMISSION OF ORDER TO BOARD OF TRADE FOR CONFIRMATION.

8.—(1) The Commissioners shall submit any order made by them under this Act to the Board of Trade for confirmation, accompanied by such particulars and plans as may be required by the Board, and shall also make and lay before the Board with the order a report stating the objections which have been made to the application, and the manner in which they have been dealt with, and any other matters in reference to the order which the Commissioners may think fit to insert in the report.

(2) The Board of Trade shall give public notice of any order so submitted to them in such manner as they think best for giving information thereof to persons interested, and shall

also state in the notice that any objections to the confirmation of the order must be lodged with the Board and the date by which those objections must be lodged.

CONSIDERATION OF ORDER BY BOARD OF TRADE.

9.—(1) The Board of Trade shall consider any order submitted to them under this Act for confirmation with special reference to—

(*a*) The expediency of requiring the proposals to be submitted to Parliament; and

(*b*) the safety of the public; and

(*c*) any objection lodged with them in accordance with this Act.

(2) The Light Railway Commissioners shall, so far as they are able, give to the Board of Trade any information or assistance which may be required by the Board for the purpose of considering any order submitted to them or any objection thereto.

(3) If the Board of Trade on such consideration are of opinion that by reason of the magnitude of the proposed undertaking, or of the effect thereof on the undertaking of any railway company existing at the time, or for any other special reason relating to the undertaking, the proposals of the promoters ought to be submitted to Parliament, they shall not confirm the order.

(4) The Board of Trade shall modify the provisions of the order for ensuring the safety of the public in such a manner as they consider requisite or expedient.

(5) If any objection to the order is lodged with the Board of Trade and not withdrawn, the Board of Trade shall consider the objection and give to those by whom it is made an opportunity of being heard, and if after consideration they decide that the objection should be upheld, the Board shall not confirm the order, or shall modify the order so as to remove the objection.

(6) The Board of Trade may at any time, if they think fit, remit the order to the Light Railway Commissioners for further consideration, or may themselves hold or institute a local inquiry, and hear all parties interested.

CONFIRMATION OF ORDER BY BOARD OF TRADE.

10.—The Board of Trade may confirm the order with or without modifications as the case may require, and an order so confirmed shall have effect as if enacted by Parliament, and shall be conclusive evidence that all the requirements of this Act in respect of proceedings required to be taken before the making of the order have been complied with.

PROVISIONS WHICH MAY BE MADE BY THE ORDER.

11.—An order under this Act may contain provisions consistent with this Act for all or any of the following purposes—

(*a*) the incorporation, subject to such exceptions and variations as may be mentioned in the order, of all or any of the provisions of the Clauses Acts as defined by this Act. Provided that where it appears to the Board of Trade that variations of the Lands Clauses Acts are required by the special circumstances of the case, the Board of Trade shall make a special report to Parliament on the subject, and that nothing in this section shall authorise any variation of the provisions of the Lands Clauses Acts with respect to the purchase and taking of land otherwise than by agreement; and

(*b*) the application, if and so far as may be considered necessary, of any of the enactments mentioned in the Second Schedule to this Act (being enactments imposing obligations on railway companies with respect to the safety of the public and other matters); and

(*c*) giving the necessary powers for constructing and working the railway, including power to make agreements with railway and other companies for the purpose; and

(*d*) giving any railway company any power required for carrying the order into effect; and

(*e*) the constitution as a body corporate of a company for the purpose of carrying out the objects of the order; and

(*f*) the representation on the managing body of the railway of any council who advance, or agree to advance, any money for the purpose of the railway; and

(*g*) authorising a council to advance or borrow money for the purposes of the railway, and limiting the amount to be so advanced or borrowed, and regulating the terms on which any money is to be so advanced or borrowed; and

(*h*) the manner in which the profits are to be divided, where an advance is made by a council to a light railway company as part of the share capital of the company; and

(*i*) the proper audit of the accounts of the managing body of the railway where the managing body is not a local authority and the time within which the railway must be constructed; and

(*j*) fixing the maximum rates and charges for traffic; and

(*k*) in the case of a new company, requiring the company to make a deposit, and providing for the time of making and the application of the deposit; and

(*l*) empowering any local authority to acquire the railway; and

(*m*) any other matters, whether similar to the above or not, which may be considered ancillary to the objects of the order or expedient for carrying those objects into effect.

Application of General Railway Acts.

12.—(1) The Clauses Acts, as defined by this Act, and the enactments mentioned in the Second Schedule to this Act, shall not apply to a light railway authorised under this Act except so far as they are incorporated or applied by the order authorising the railway.

(2) Subject to the foregoing provisions of this Act and to any special provisions contained in the order authorising the railway, the general enactments relating to railways shall apply to a light railway under this Act in like manner as they apply to any other railway; and for the purposes of those enactments, and of the Clauses Acts so far as they are incorporated or applied by the order authorising the railway, the light railway company shall be deemed a railway company, and the order under this Act a special Act, and any provision thereof a special enactment. Provided that a light railway shall not be deemed to be a railway within the meaning of the Railway Passenger Duty Act, 1842 (5 and 6 Vict., c. 79), and that no duties shall hereafter be levied in respect of passengers conveyed on a light railway constructed under this Act in respect of the conveyance of such passengers upon such railway.

Mode of Settling Purchase-Money and Compensation for Taking of Land.

13.—(1) Where any order under this Act incorporates the Lands Clauses Acts, any matter which under those Acts may be determined by the verdict of a jury, by arbitration, or by two justices, shall for the purposes of the order be referred to and determined by a single arbitrator appointed by the parties, or if the parties do not concur in the appointment of a single arbitrator then by the Board of Trade, and the provisions of this Act shall apply with respect to the determination of any such matter in lieu of those of the Lands Clauses Acts relating thereto. Provided that in determining the amount of compensation, the arbitrator shall have regard to the extent to which the remaining and contiguous lands and hereditaments belonging to the same proprietor may be benefited by the proposed light railway.

(2) The Board of Trade may, with the concurrence of the Lord Chancellor, make rules fixing a scale of costs to be applicable on any such arbitration, and may, by such rules, limit the cases in which the costs of counsel are to be allowed.

(3) The Arbitration Act, 1889 (52 and 53 Vict., c. 49), shall apply to any arbitration under this section.

PAYMENT OF PURCHASE MONEY OR COMPENSATION.

14.—Any order under this Act may, notwithstanding anything in the Lands Clauses Acts, authorise the payment to trustees of any purchase money or compensation not exceeding five hundred pounds.

PROVISIONS AS TO BOARD OF TRADE.

15.—(1) If the Board of Trade hold a local inquiry for the purposes of this Act, Part I. of the Board of Trade Arbitrations, etc., Act, 1874 (37 and 38 Vict., c. 40), shall apply to any inquiry so held as if—

(*a*) The inquiry was held on an application made in pursuance of a special Act; and

(*b*) the parties making the application for the order authorising the light railway, and in the case of an inquiry held with reference to an objection made to any such application, the persons making the objection in addition, were parties to the application within the meaning of section three of the Act.

(2) The Board of Trade may make such rules as they think necessary for regulating the procedure under this Act, whether before the Board of Trade or before the Light Railway Commissioners, and any other matters which they may think expedient to regulate by rule for the purpose of carrying this Act into effect.

(3) There shall be charged in respect of proceedings under this Act before the Board of Trade or the Light Railway Commissioners such fees as may be fixed by the Treasury on the recommendation of the Board of Trade.

(4) Any expenses of the Board of Trade under this Act shall, except so far as provision is made for their payment by or under this Act, be defrayed out of moneys provided by Parliament.

(5) The Board of Trade shall present to Parliament annually a report of their proceedings and of the proceedings of the Light Railway Commissioners under this Act.

EXPENSES OF LOCAL AUTHORITIES.

16.—(1) The council of any county, borough, or district may pay any expenses incurred by them and allowed by the Light Railway Commissioners with reference to any application for an order authorising a light railway under this Act, in the case of a county council as general expenses, in the case of a borough council out of the borough fund or rate, and in the case of a district council other than a borough council as general expenses under the Public Health Acts.

Provided that any expenses incurred by a county council under this Act may be declared by the order authorising the railway, or, in the event of an unsuccessful application for such an order, by the Light Railway Commissioners, to be exclusively chargeable on certain parishes only in the county, and those expenses shall be levied accordingly as expenses for a special county purpose under the Local Government Act, 1888 (51 and 52 Vict., c. 41).

(2) Where the council of any county, borough, or district are authorised to expend any money by an order authorising a light railway under this Act, they may raise the money required—

(*a*) If the expenditure is capital expenditure, by borrowing in manner authorised by the order; and

(*b*) if the expenditure is not capital expenditure, as if it was on account of the expenses of an application under this Act.

(3) The Board of Trade may from time to time, on the application of any council, extend, subject to the limitations of this Act, the limit of the amount which the council are authorised by an order under this Act to borrow, or to advance to a light railway company, and the limit so extended shall be substituted for the limit fixed by the order.

(4) Where an order under this Act authorises any council to borrow for the purposes of a light railway, suitable provision shall be made in the order for requiring the replacement of the money borrowed within a fixed period not exceeding sixty years, either by means of a sinking fund or otherwise.

(5) Any profits made by a council in respect of a light railway shall be applied in aid of the rate out of which the expenses of the council in respect of the light railway are payable.

(6) Where a rate is levied for meeting any expenditure under this Act, the demand note for the rate shall state, in a form prescribed by the Local Government Board, the proportion of the rate levied for that expenditure.

Joint Committees.

17.—(1) The councils of any county, borough, or district may appoint a joint committee for the purpose of any application for an order authorising a light railway under this Act, or for the joint construction or working of a light railway, or for any other purpose in connection with such a railway for which it is convenient that those councils should combine.

2. The provisions of the Local Government Act, 1888 (51 and 52 Vict. c. 41), or of the Local Government Act, 1894 (56 and 57 Vict. c. 73), as the case may be, with respect to joint committees, shall apply to any joint committee appointed for the purpose of this Act by any councils who could appoint a joint committee under those Acts, but where the councils have no power under those Acts to appoint a joint committee the provisions in the Third Schedule to this Act shall apply.

Working of Ordinary Railway as Light Railway.

18.—Where a company have power to construct or work a railway, they may be authorised by an order under this Act to construct and work or to work the railway or any part of it as a light railway under this Act.

Power of Owners to Grant Land or Advance Money for a Light Railway.

19.—(1) Where any person has power, either by statute or otherwise, to sell and convey any land for the purpose of any works of a light railway, he may, with the sanction of the Board of Agriculture given under this section, convey the land for that purpose, either without payment of any purchase money or compensation or at a price less than the real value, and may so convey it free from all encumbrances thereon.

(2) Whenever any person who is a landowner within the meaning of the Improvement of Land Act, 1864 (27 and 28 Vict. c. 114), contributes any money for the purpose of any works of a light railway, the amount so contributed may, with the sanction of the Board of Agriculture given under this section, be charged on the land of the landowner improved by the works, in the same manner and with the like effect as in the case of a charge under that Act.

(3) The Board of Agriculture shall not give their sanction under this section unless they are satisfied that the works for which the land is conveyed or the money is contributed will effect a permanent increase in the value of the land held by the same title or of other land of the same landowner exceeding, in the case of a conveyance of land, that which is, in the opinion of the Board of Agriculture, the real value of the land conveyed or the difference between that value and the price, as the case may be, and in the case of a contribution of

money the amount contributed: Provided also, that if the land proposed to be conveyed is subject to incumbrances, the Board of Agriculture, before giving their sanction under this section, shall cause notice to be given to the incumbrancers, and shall consider the objections, if any, raised by them.

Power to Grant Crown Lands.

20.—The Commissioners of Woods shall, on behalf of Her Majesty, have the like powers to convey Crown lands as are by this Act conferred upon persons having power, either by statute or otherwise, to sell and convey lands, except that in the case of Crown lands the sanction of the Treasury shall be substituted for the sanction of the Board of Agriculture.

Provision as to Commons.

21.—(1) No land being part of any common, and no easement over or affecting any common, shall be purchased, taken, or acquired under this Act without the consent of the Board of Agriculture, and the Board shall not give their consent unless they are satisfied that, regard being had to all the circumstances of the case, such purchase, taking, or acquisition is necessary; that the exercise of the powers conferred by the order authorising the railway will not cause any greater injury to the common than is necessary; and that all proper steps have been taken in the interest of the commoners and of the public to add other land to the common (where this can be done) in lieu of the land taken, and where a common is divided to secure convenient access from one part of the common to the other.

(2) The expression "common" in this section shall include any land subject to be enclosed under the Inclosure Acts, 1845 to 1882, any metropolitan common within the meaning of the Metropolitan Commons Acts, 1866 to 1878, and any town or village green.

Preservation of Scenery and Objects of Historical Interest.

22.—If any objection to any application for authorising a light railway is made to the Light Railway Commissioners, or if any objection to any draft order is made to the Board of Trade on the ground that the proposed undertaking will destroy or injure any building or other object of historical interest, or will injuriously affect any natural scenery, the Commissioners and the Board of Trade respectively shall consider any such objection, and give to those by whom it is made a proper opportunity of being heard in support of it.

Junctions with Existing Railways.

23.—Any junction of a light railway authorised under this Act with any existing railway shall, so far as is in the opinion of the Board of Trade reasonably practicable, avoid interference with lines of rails used for passenger traffic.

Amendment of Order.

24.—An order authorising a light railway under this Act may be altered or added to by an amending order made in like manner and subject to the like provisions as the original order.

Provided that—

(*a*) The amending order may be made on the application of any authority or person; and

(*b*) the Board of Trade, in considering the expediency of requiring the proposals for amending the order to be submitted to Parliament, shall have regard to the scope and provisions of the original order; and

(*c*) the amending order shall not confer any power to acquire the railway except with the consent of the owners of the railway.

PROVISION AS TO TELEGRAPHS.

25.—The definition of "Act of Parliament" in the Telegraph Act, 1878 (41 and 42 Vict., c. 76), shall include an order authorising a light railway under this Act.

APPLICATION TO SCOTLAND.

26.—This Act shall apply to Scotland with the following modifications:—

(1) In section five of this Act the expression "Secretary for Scotland" shall be substituted for the expressions "Board of Agriculture" and "Board of Trade" respectively, occurring in that section.

(2) References to the council of any county, borough, or district shall be construed as references to the county council of any county, or the town council, or where there is no town council the police commissioners, of any burgh, or the commissioners of any police burgh, or the district committee of any district under the Local Government (Scotland) Act, 1889 (52 and 53 Vict., c. 50); or in any county where there is no district committee any two or more parish councils may combine.

(3) "Arbiter" shall be substituted for "arbitrator," and that arbiter shall be deemed to be a single arbiter within the meaning of the Lands Clauses Acts, and in lieu of the provisions of the Arbitration Act, 1889, the provisions of the Lands Clauses Acts with respect to an arbitration shall apply, except the provisions of the said Acts as to the expenses of the arbitration, in lieu of which the following provision shall have effect, namely, the expenses of the arbitration and incident thereto shall be in the discretion of the arbiter, who may direct to and by whom and in what manner those expenses, or any part thereof, shall be paid, and may tax or settle the amount of expenses to be so paid, or any part thereof, and may award expenses to be paid as between agent and client.

(4) The Lord President of the Court of Session shall be substituted for the Lord Chancellor.

(5) The money necessary to defray expenditure, not being capital expenditure incurred by a county council in pursuance of this Act, shall be raised by a rate imposed along with, but as a separate rate from, the rate for maintenance of roads (hereinafter referred to as "the road rate) leviable under the Roads and Bridges (Scotland) Act, 1878 (41 and 42 Vict., c. 51), upon lands and heritages within the county, or the district, or the parish, as the case may be. The money necessary to defray expenditure similarly incurred by a town council, or police commissioners, or burgh commissioners, shall be raised by a rate imposed along with, but as a separate rate from, the police assessment or burgh general assessment, as the case may be. If the expenditure incurred is capital expenditure it shall be raised by borrowing in the manner authorised by the order; the rate chargeable for repayment of capital, including interest and expenses, being the same rate as is liable for maintenance as aforesaid.

(6) The provisions relating to district councils shall apply to district committees or combinations of parish councils, subject to the following modifications—

(*a*) A district committee shall not be entitled to make an application under section two hereof except with the consent of the county council given at a special or statutory meeting of the council, of which one month's special notice, setting forth the purpose of the meeting, shall have been sent to each councillor.

(*b*) A resolution to give such consent shall not be passed by the council unless two-thirds of the councillors present and voting at the special or statutory meeting concur in the resolution.

(*c*) Nothing in this Act shall authorise a district committee to raise money by rate or loan, but any money necessary to defray expenditure, not being capital

expenditure incurred by it in pursuance of this Act, shall be raised by the county council by a rate imposed along with but as a separate rate from the road rate; and any money necessary to defray capital expenditure shall be raised by the county council by borrowing in the manner authorised by the order, as in section sixteen hereof mentioned;

7. The expression "Clauses Acts" shall mean the Lands Clauses Acts, the Railways Clauses Consolidation (Scotland) Act, 1845, the Companies Clauses Consolidation (Scotland) Act, 1845, the Companies Clauses Act, 1863, the Railways Clauses Act, 1863, and the Companies Clauses Act, 1869;

(8) References to the Local Government Act, 1888, and the Local Government Act, 1894, shall be construed as references to the Local Government (Scotland) Act, 1889 (52 and 53 Vict. c. 50), and the Local Government (Scotland) Act, 1894 (57 and 58 Vict. c. 58).

(9) In order to carry out in Scotland the provisions contained in sub-section (1) (*c*) of section five of this Act, it shall be the duty of the assessor of railways and canals, as regards any parish to which the said sub-section (1) (*c*) applies, to enter on his valuation roll either the annual value of the light railway within such parish ascertained in the terms of the Valuation of Lands (Scotland) Acts, or the annual value at which the land occupied by or for the purposes of the light railway would have been assessed if it had remained in the condition in which it was immediately before it was acquired for the purposes of the railway, whichever is less;

(10) Where a light railway constructed under the powers of this Act is owned or leased by an existing railway company, such light railway shall not be valued by the said assessor as part of the general undertaking of the railway company, but shall be valued as a separate undertaking.

EXTENT OF ACT.

27.—This Act shall not extend to Ireland.

DEFINITIONS.

28.—In this Act, unless the context otherwise requires :—

The expression "light railway company" includes any person or body of persons, whether incorporated or not, who are authorised to construct, or are owners or lessees of, any light railway authorised by this Act, or who are working the same under any working agreement:

The expression "Clauses Acts" means the Lands Clauses Acts, the Railways Clauses Consolidation Act, 1845, and the Railways Clauses Act, 1863, and the Companies Clauses Act, 1845 to 1889:

The expression "share capital" includes any capital, whether consisting of shares or of stock, which is not raised by means of borrowing.

SHORT TITLE.

29.—This Act may be cited as the Light Railways Act, 1896.

FIRST SCHEDULE (SECTION 3).

Mode of Passing Special Resolutions.

1. The resolution approving of the intention to make the application must be passed at a meeting of the council.

2. The resolution shall not be passed unless a month's previous notice of the resolution has been given in manner in which notices of meetings of the council are usually given.

3. The resolution shall not be passed unless two-thirds of the members of the council present and voting concur in the resolution.

SECOND SCHEDULE (SECTION 12).

Enactments relating to Safety, etc.

Session and Chapter.	Title or Short Title.	Enactment referred to.
2 and 3 Vict., c. 45.	An Act to amend an Act of the fifth and sixth years of the reign of his late Majesty King William the Fourth relating to highways.	The whole Act.
5 and 6 Vict., c. 55.	The Railway Regulation Act, 1842.	Sections four, five, six, nine, ten.
9 and 10 Vict., c. 57.	An Act for regulating the gauge of railways.	The whole Act.
31 and 32 Vict., c. 119.	The Regulation of Railways Act, 1868.	Sections nineteen, twenty, twenty-two, twenty-seven, twenty-eight, and twenty-nine.
34 and 35 Vict., c. 78.	The Regulation of Railways Act, 1871.	Section five.
36 and 37 Vict., c. 76.	The Railway Regulation Act (Returns of signal arrangements, working, &c.), 1873.	Sections four and six.
41 and 42 Vict., c. 20.	The Railway Returns (Continuous Brakes) Act, 1878.	The whole Act.
46 and 47 Vict., c. 34.	The Cheap Trains Act, 1883.	Section three.
52 and 53 Vict., c. 57.	The Regulation of Railways Act, 1889.	The whole Act.

THIRD SCHEDULE (SECTION 17).

Joint Committees.

(*a*) Any council taking part in the appointment of a joint committee may delegate to the committee any power which the council may exercise for the purpose for which the committee is appointed.

(*b*) A council shall not be authorised to delegate to a joint committee any power of making a rate or borrowing money.

(*c*) Subject to the terms of the delegation, the joint committee shall have the same power in all respects with respect to any matter delegated to them, as the councils appointing it, or any of them.

(*d*) The members of the joint committee may be appointed at such times and in such manner, and shall hold office for such period, as may be fixed by the councils appointing them:

Provided that a member shall not hold office beyond the expiration of fourteen days after the day for the ordinary election of councillors of the council by which he was appointed, or in Scotland after the day for the ordinary election of councillors of the council of the county in which the district is situated.

(*e*) The costs of a joint committee shall be defrayed by the councils by whom the committee is appointed, in such proportions as they may agree upon, and in the event of their differing in opinion, as may be determined by the Board of Trade on an application by either council.

(*f*) When any of the councils joining in the appointment of a joint committee is a county or district council other than a borough council, the accounts of the joint committee shall be audited in like manner and with the like power to the officer auditing the accounts, and with the like incidents and consequences as the accounts of a county council.

(*g*) The chairman at any meeting of the committee shall have a second or casting vote.

(*h*) The quorum, proceedings, and place of meeting of a committee, whether within or without the area within which the committee are to exercise their authority, shall be such as may be determined by regulations jointly made by the councils appointing the committee, and in the event of their differing in opinion, as may be determined by the Board of Trade on an application by either council.

(*i*) Subject to these regulations, the quorum, proceedings, and place of meeting, whether within or without the area within which the committee are to exercise their jurisdiction, shall be such as the committee direct,

TABLE OF THE PRINCIPAL ACTS RELATING TO RAILWAYS.

Carriers Protection Act...	1830	1 Will. IV., c. 68
Conveyance of Mails by Railways	1837	1 and 2 Vict., c. 98
Highways Act (Amendment) ...	1839	2 and 3 Vict., c. 45
Regulation of Railways Act	1840	3 and 4 Vict., c. 97
Regulation of Railways Act	1842	5 and 6 Vict., c. 55
Regulation of Railways Act	1844	7 and 8 Vict., c. 85
Companies Clauses Consolidation Act...	1845	8 and 9 Vict., c. 16
Lands Clauses Consolidation Act	1845	8 and 9 Vict., c. 18
Railways Clauses Consolidation Act	1845	8 and 9 Vict., c. 20
Documentary Evidence...	1845	8 and 9 Vict., c. 113
Gauge of Railways	1846	9 and 10 Vict., c. 57
Railway Clearing System	1850	13 and 14 Vict., c. 33
Abandonment and Dissolution of Railways	1850	13 and 14 Vict., c. 83
Railway and Canal Traffic	1854	17 and 18 Vict., c. 31
Railway Companies Arbitration Act	1859	22 and 23 Vict., c. 59
Lands Clauses Consolidation Act (Amendment)	1860	23 and 24 Vict., c. 106
Railways Clauses Act	1863	26 and 27 Vict., c. 92
Companies Clauses	1863	26 and 27 Vict., c. 118
Improvement of Land ...	1864	27 and 28 Vict., c. 114
Railway Companies Powers	1864	27 and 28 Vict., c. 120
Railways Construction Facilities Act ...	1864	27 and 28 Vict., c. 121
Railways Companies Securities Act	1866	29 and 30 Vict., c. 108
Railway Companies Act	1867	30 and 31 Vict., c. 127
Regulation of Railways Act	1868	31 and 32 Vict., c. 119
Lands Clauses Consolidation Act (Amendment)	1869	32 and 33 Vict., c. 18
Companies Clauses Act (Amendment)	1869	32 and 33 Vict., c. 48
Abandonment of Railways	1869	32 and 33 Vict., c. 114
Railways (Powers and Construction) Amendment Act	1870	33 and 34 Vict., c. 19
Regulation of Railways Act	1871	34 and 35 Vict., c. 78
Railway Rolling Stock Protection Act	1872	35 and 36 Vict., c. 50
Railway and Canal Traffic	1873	36 and 37 Vict., c. 48
Regulations of Railways Act ...	1873	36 and 37 Vict., c. 76
Board of Trade Arbitrations, Inquiries, etc. ..	1874	37 and 38 Vict., c. 40
Continuous Brakes	1878	41 Vict., c. 20
Contagious Diseases (Animals)	1878	41 and 42 Vict., c. 74
Telegraph Act ...	1878	41 and 42 Vict., c. 76
Commonable Rights (Compensation) ...	1882	45 Vict., c. 15.
Post Office (Parcels)	1882	45 and 46 Vict., c. 74
Cheap Trains Act	1883	46 and 47 Vict., c. 34
Railway and Canal Traffic	1888	51 and 52 Vict., c. 25
Regulation of Railways Act	1889	52 and 53 Vict., c. 57

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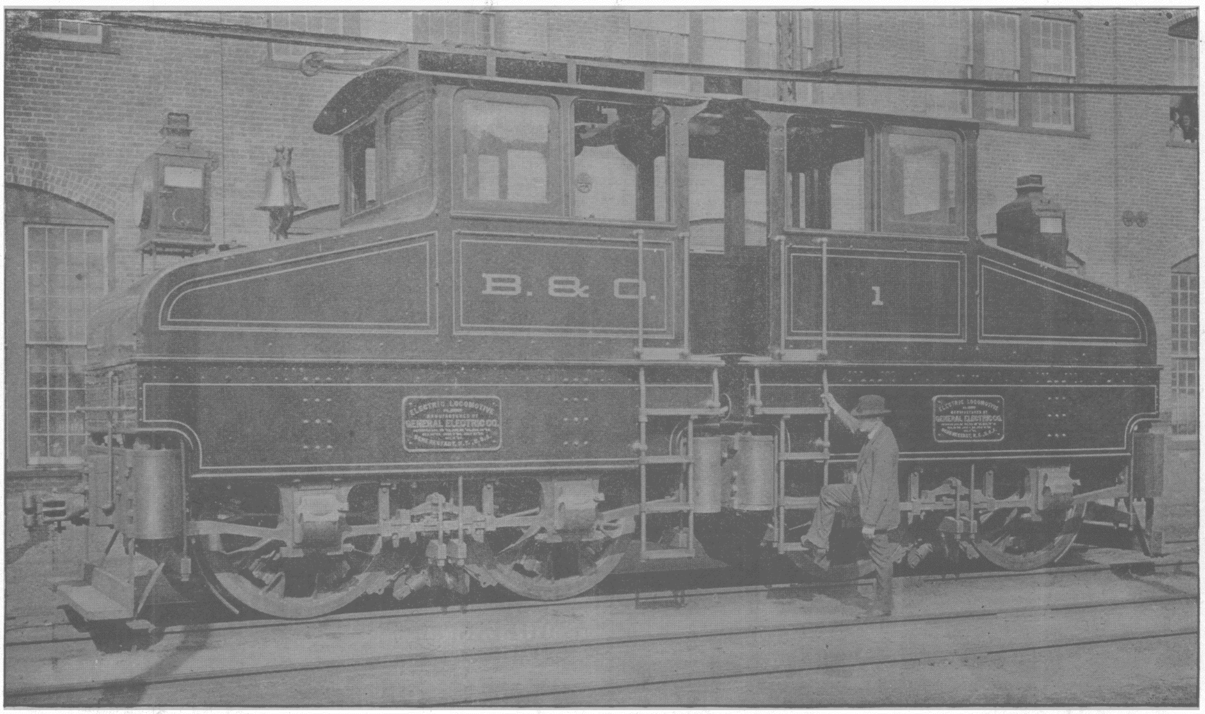

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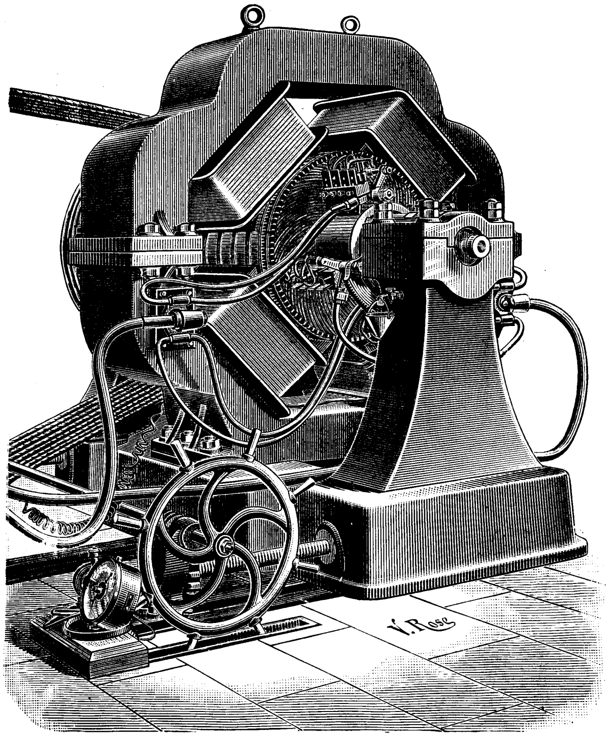

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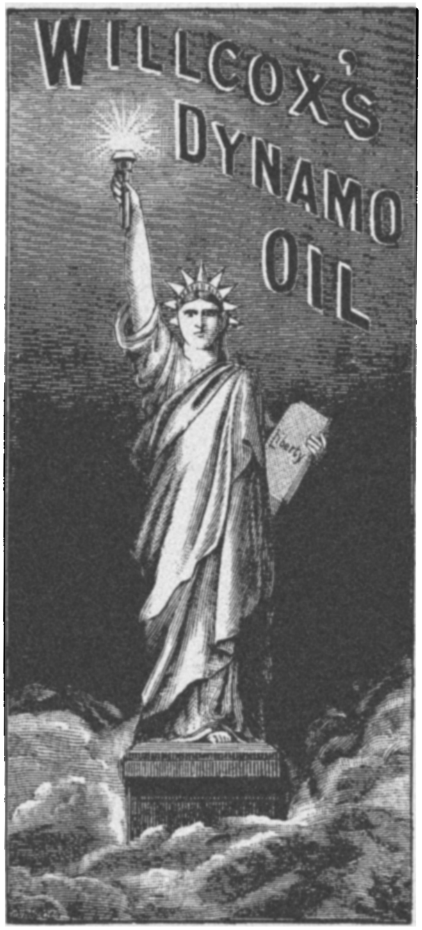

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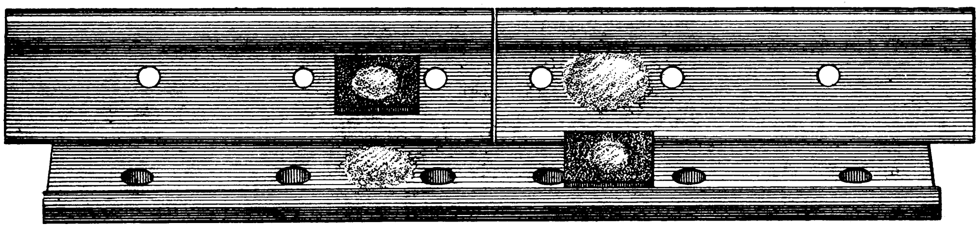

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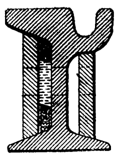
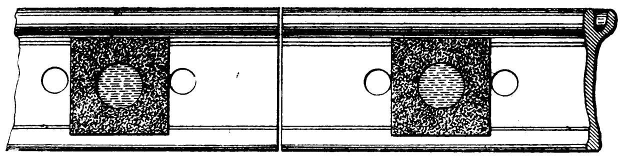
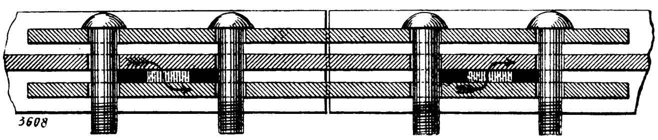


END SECTION THROUGH BOND, RAIL AND FISHPLATE.



SIDE VIEW OF RAILS WITH BOND CASES IN POSITION BEFORE FISHPLATE IS PUT ON.



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FROM THE LABORATORY OF THOMAS A. EDISON, ORANGE, N.J., March 2, 1895.

The Bond has been TESTED FIVE YEARS, under ground at my laboratory. At the end of that time it was PERFECT.

THOS. A. EDISON.

CONSOLIDATED TRACTION Co., Jersey City, July 3, 1895.

I have used *thousands* of the Plastic Bonds with *entire satisfaction.* DAVID YOUNG, General Manager.

ORANGE, N.J., March 14, 1895.

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SUBURBAN TRACTION CO.

SUBURBAN TRACTION Co., Orange, N.J., August 13, 1895.

We found that we could put it in much faster than the best type of copper bond, and as we know from our FIVE YEARS' EXPERIENCE with it, that it WILL NOT RUST NOR BREAK, we take pleasure in recommending it to all electric roads, confident that it will save money to them in first cost and in running expenses.

WATSON WHITTLESEY, Receiver.

THE CLEVELAND ELECTRIC RAILWAY Co., Cleveland, Ohio, December 18, 1895.

The average drop with the copper bonds was 0.28 volts; at the same time and in same rail the average drop of your Bond was but 0.0125 volts. I am more than satisfied that the Plastic Bond is the ONLY PERFECT BOND ever used.

R. M. FULLER, Electrician.

NIAGARA FALLS & LEWISTON RAILWAY Co., Niagara Falls, N.Y., Feb. 7, 1896.

We have bonded about ten miles of our road with this bond and believe it to be a very good thing.

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J. K. BROOKS, Superintendent.

CAMDEN HORSE RAILROAD Co., Camden, N.J., February 18, 1896.

We have recently installed the Plastic Bond on a new section of our road. We found that one man to prepare and amalgamate the fish-plates and one man to set the Bond and cork at time fish-plate was located, was all that was necessary. We used men out of the regular construction gang for this work. My judgment is that for practically the same results as regards "drop" the expense of installation of the Plastic Bond is less than any other type of bond used. I consider the Edison-Brown Plastic Bond a VERY DECIDED SUCCESS.

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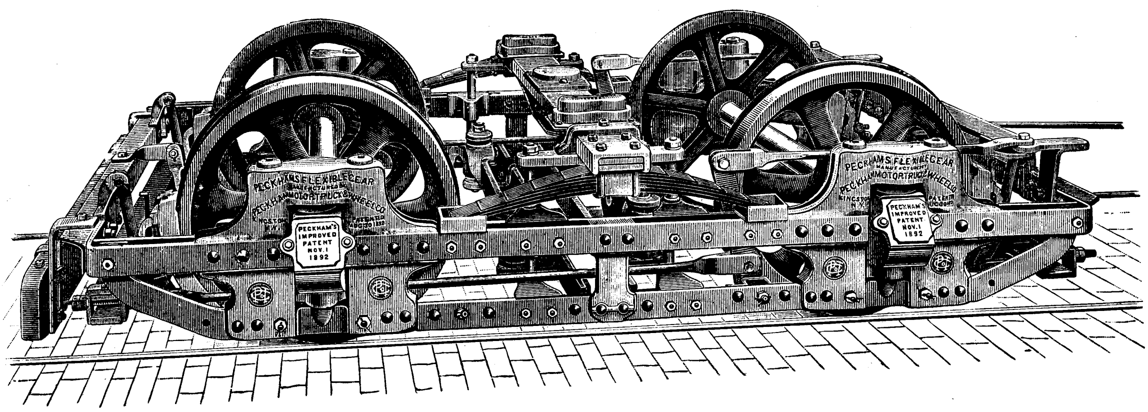

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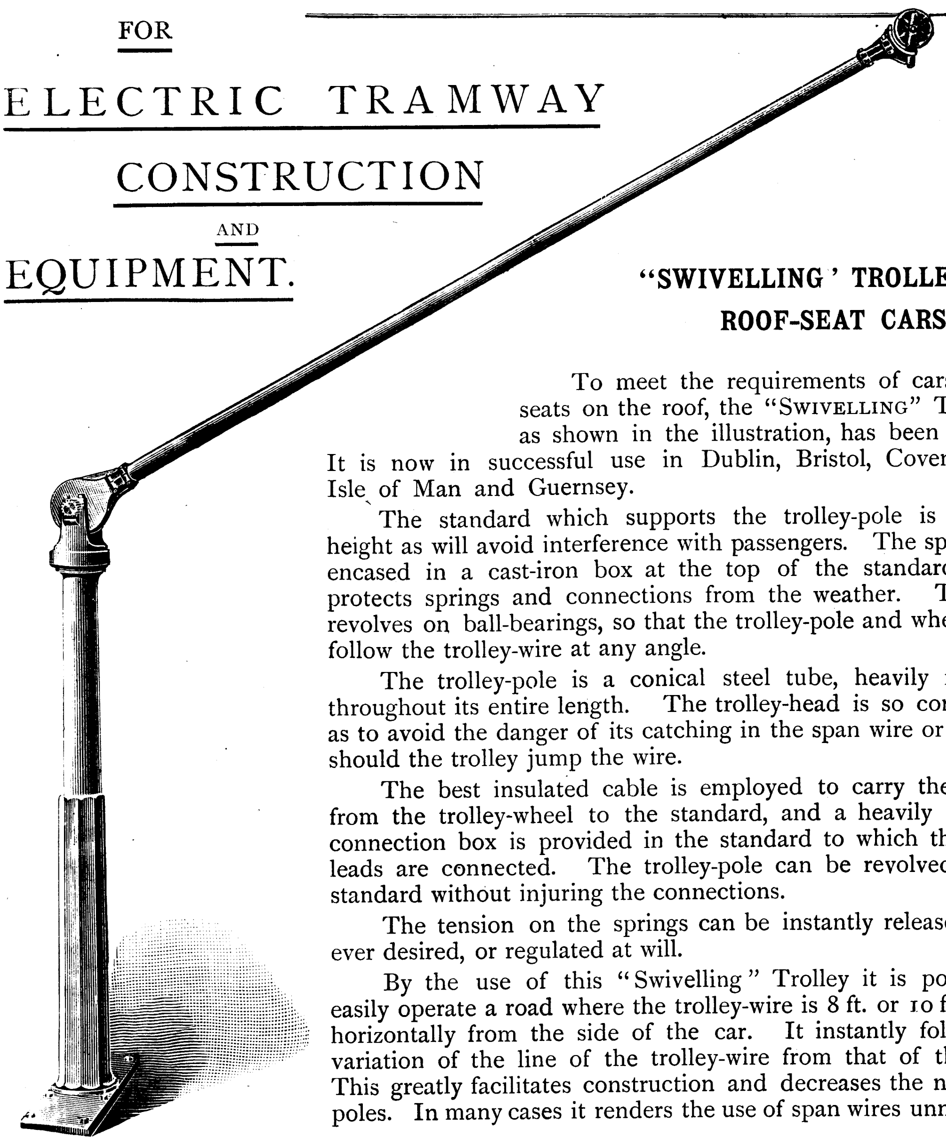

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The best insulated cable is employed to carry the current from the trolley-wheel to the standard, and a heavily insulated connection box is provided in the standard to which the motor leads are connected. The trolley-pole can be revolved on the standard without injuring the connections.

The tension on the springs can be instantly released whenever desired, or regulated at will.

By the use of this "Swivelling" Trolley it is possible to easily operate a road where the trolley-wire is 8 ft. or 10 ft. distant horizontally from the side of the car. It instantly follows any variation of the line of the trolley-wire from that of the track. This greatly facilitates construction and decreases the number of poles. In many cases it renders the use of span wires unnecessary.

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